United States Environmental Protection Agency
Region 2

CONTAMINATED SEDIMENT TECHNICAL ADVISORY GROUP CONSIDERATION MEMORANDUM

LOWER PASSAIC RIVER RESTORATION PROJECT

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LOWER PASSAIC RIVER RESTORATION PROJECT
CSTAG CONSIDERATION MEMORANDUM

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CSTAG CONSIDERATION MEMORANDUM

BACKGROUND

The Lower Passaic River Restoration Project (the Study) is a comprehensive study of the 17-mile tidal portion of the Passaic River and its approximately 118 square-mile watershed (hereinafter referred to as the Study Area) in northern New Jersey. The 17-mile tidal portion of the Lower Passaic River is an operable unit of the Diamond Alkali Superfund Site in Newark, New Jersey. During the course of the Study, sediments in the lower eight miles of the river were identified as the major source of contamination to the 17-mile Study Area and to Newark Bay. Those highly contaminated sediments are causing unacceptable human health and ecological risks, because people and animals are eating contaminated fish and crabs from the river. Through a risk assessment and Focused Feasibility Study (FFS; Malcolm Pirnie, Inc., 2007c), remedial alternatives for a Source Control Early Action are being evaluated to address these contaminated sediments in the lower eight miles of the Passaic River. The Source Control Early Action, which would be a final action for the sediments in the lower eight miles, is intended to take place in the near term, while the comprehensive 17-mile Study is on-going.

The integrated Study is being implemented by the U.S. Environmental Protection Agency (USEPA) under the Superfund Program; by the U.S. Army Corps of Engineers (USACE) and New Jersey Department of Transportation (NJDOT) under the Water Resources Development Act; and by the U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and New Jersey Department of Environmental Protection (NJDEP) as Natural Resource Trustees. The Study is partly funded by the Cooperating Parties Group (CPG) that is comprised of over 70 potentially responsible parties for the river's contamination. The purpose of the Study is to gather data needed to make decisions on remediating contamination in the river to reduce human

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health and ecological risks, improve the water quality of the river, improve and create aquatic habitat, improve human use, and reduce contaminant loading in the Lower Passaic River and the New York-New Jersey Harbor Estuary.

As a Tier 2 site, site evaluation and remedy selection rationale for the Lower Passaic River must be reviewed by the Contaminated Sediments Technical Advisory Group (CSTAG). This memorandum presents an evaluation of the Source Control Early Action in the context of the 11 Risk Management Principles identified by USEPA in Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-08 (USEPA, 2002a), which is also included as Appendix A of the Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA, 2005).

ENVIRONMENTAL SETTING

The Passaic River is a medium-sized river that drains north-central New Jersey and flows into Newark Bay, part of the New York - New Jersey Harbor Estuary. The river flows through one of the most densely populated and industrialized regions in the United States. The Lower Passaic River, the focus of this document, is the lower 17 miles of the river that are a tidal estuary. Just above the head of tide at River Mile (RM) 17, the Dundee Dam presents a major hydraulic boundary. The downstream end of the river is at the confluence with Newark Bay, between Newark and Kearny, New Jersey. There are three named tributaries to the Lower Passaic River: Saddle River, Second River and Third River. Figure 1 is a map showing the course of the Lower Passaic River and its major hydraulic boundaries.

In the early nineteenth century the Lower Passaic River watershed was one of the major centers of the American industrial revolution, with manufacturing, and many industrial operations established along the river's banks, including cotton mills, manufactured gas plants, paper manufacturing and recycling facilities, chemical manufacturing facilities, and others. Until the Clean Water Act was enacted in the early 1970s, these facilities

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used the river for wastewater disposal unchecked. These industrial facilities and adjacent municipalities discharged contaminants to the river, including dioxins, petroleum hydrocarbons, polychlorinated biphenyls (PCB), pesticides, and metals.

Several large dredging projects at the beginning of the twentieth century established and maintained a navigation channel through more than 15 miles of the river. However, since the 1940s, there has been little maintenance dredging and none since the early 1980s. Consequently, the river has accumulated substantial sediment deposits particularly in the lower eight miles, measuring up to 25 feet thick. Less sedimentation occurred upstream because of the faster flowing narrower channel. Because the sediment accumulation occurred coincidently with unchecked discharges of environmentally persistent chemicals with affinity for sediment particles, the depositing sediment retained high loads of the contamination discharged. As the river approaches its pre-dredged channel depth and begins reworking older sediments, the thick contaminated sediment beds now are a source of continuing contamination to the river and to the larger New York - New Jersey Harbor Estuary.

The Lower Passaic River is relatively narrow compared to its tidal exchange, which can account for one third of the water volume in the river at high tide. This makes the tidal surge a prominent dynamic force in the river. Tidal mixing distributes contamination throughout the lower eight miles, as well as upriver to at least RM13 and downriver into Newark Bay and the New York – New Jersey Harbor Estuary. During the largest tidal cycles and during storm events, the sediments are reworked, exposing contaminants from the deeper sediment beds and redistributing them on the surface. Year-to-year comparisons of bathymetric surveys of the river bottom show that the sediments dynamically erode and deposit in shifting sequences, confirming that older contaminated sediments continue to be resuspended. As a fraction of all of the solids sources to the Lower Passaic, resuspension of deeper sediments comprises about 10 percent of the total annual deposition. However, resuspension accounts for over 95 percent of the dioxin and a significant portion of PCBs, pesticides, and mercury in recently deposited sediments.

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In this way concentrations of contaminants in the surface sediments remain at elevated levels (see Table 2).

The Lower Passaic River is also a major source of contaminants to Newark Bay. Sediment transport from the Lower Passaic River to Newark Bay delivers the contaminants found in Newark Bay's surficial sediments, particularly dioxin. It is estimated that the Lower Passaic River contributes approximately 10 percent of the average annual amount of sediment accumulating in Newark Bay, and more than 80 percent of the dioxin accumulating in the Bay. A recent study of dioxin contamination in New York Harbor (Chaky, 2003) traces the Lower Passaic River dioxin signature through the entire New York – New Jersey Harbor Estuary. The Lower Passaic River also delivers approximately 20 percent of the mercury to Newark Bay.

Sediment contamination is not the only problem in the Lower Passaic River. The communities that line the river banks are prone to flooding. Development of the banks and the watershed has eliminated vital wetlands and floodplains, so that flood events pose economic and public safety risks.

CONCEPTUAL SITE MODEL

Table 1 presents many of the important observations about the state of the river and sediments that have been made through more than a decade of investigations and analyses. These geochemical and geomorphologic studies include: surface sediment sampling, low resolution sediment coring, high resolution sediment coring, water column sampling, side scan sonar and bathymetric surveys, geotechnical coring, and tissue and biota sampling.

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The Conceptual Site Model (CSM) is described by an Empirical Mass Balance that models the sources into the Lower Passaic River water column as characterized by recently deposited sediments[1] to identify the most important contributors of each major contaminant. The sources are upriver (over Dundee Dam), downriver (from Newark Bay), tributaries, Combined Sewer Overflows (CSOs), Storm Water Outfalls (SWOs), and resuspension of legacy sediments. The Source Control Early Action evaluates remedial measures targeted at the most important source of contaminants which is the resuspension of legacy sediments. The following discussion presents the weight of evidence for the significance of each potential source.

Does Contamination in Recently Deposited Sediments of the Lower Passaic Originate in Newark Bay? Tidal exchange between Newark Bay and the Lower Passaic River delivers a large mass of solids annually. Hypothetically, if these solids were to contain high levels of contaminants, then Newark Bay would also deliver a large mass of contaminants annually. This hypothesis is completely incompatible with the data.

Referring to Table 1, observations of dioxin, PCBs, Polycyclic Aromatic Hydrocarbon (PAHs), and most heavy metals would rule out Newark Bay as the source of contaminants (see Observations PR-10, PR-18, and NB-1). Recently deposited surface sediments (*i.e.,* Beryllium-7 [Be^7] bearing sediments) obtained from Newark Bay in 2005 as well as historical measurements of shallow sediments in the bay all show Newark Bay sediments to be less contaminated than those found in the Lower Passaic River. Strong declining concentration gradients exist between the river and the bay for dioxins, PCBs, cadmium, copper, chromium, and lead (see Table 2). In particular, the sediments of Newark Bay have a mean concentration of the unique dioxin 2,3,7,8-

[1] R*ecently deposited sediments* are identified by the presence of Be^7 (a naturally occurring radio isotope with a half-life of 54 days). These sediments are of particular interest because they represent the water column contaminant load at the time of deposition.

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tetrachlorodibenzodioxin (2,3,7,8-TCDD) that is an order of magnitude lower than that observed for the Lower Passaic River (see Table 2, and Observation PR-10).

An examination of the ratios of heavy metals to aluminum (a geochemical tracer for fine-grained particles) also shows a strong gradient, indicating that fine-grained particles in Newark Bay contain less cadmium, copper, chromium, and lead than those found in the Lower Passaic River (Observation NB-3). This also rules out Newark Bay as a major source of these contaminants since the gradient of the "fingerprint" of the solids in the bay shows mixing of less-contaminated, lower ratio fine-grained particles in Newark Bay with more-contaminated, high ratio particles from the Lower Passaic River.

Finally, the 2,3,7,8-TCDD to total TCDD ratio has been shown to be a diagnostic feature of the contamination of the Lower Passaic River. The dioxin ratio in Newark Bay (about 0.4) is substantially lower than that observed in the surface sediments of the Lower Passaic River (0.7). This ratio difference is quite significant and completely rules out Newark Bay as a significant dioxin source to the Lower Passaic River. Specifically, to change the ratio of Newark Bay sediments to match the ratio of the Lower Passaic River while also increasing the 2,3,7,8-TCDD concentration would require a geochemical process to preferentially concentrate 2,3,7,8-TCDD at the expense of the other tetrachlorodioxins, a process that is not known to exist.

In sum, these observations rule out the scenario of Newark Bay as a source for nearly all contaminants. The exception to this is mercury, where concentrations near the confluence of Newark Bay and the Lower Passaic River may be sufficiently high to result in some net transport of mercury from the bay to the Lower Passaic River. However, the amount of mercury transport would be limited by the relatively small local gradient and the observation that most of the solids in Newark Bay (as represented by the values at RM6 in Figure 2) have mercury concentrations below those observed in the Lower Passaic River.

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Does Contamination in Recently Deposited Sediments of the Lower Passaic River Originate in the Upper Passaic River? The Upper Passaic River delivers a large mass of solids annually to the Lower Passaic River over the Dundee Dam at RM 17. The mass of solids was estimated by Lowe *et al.* (2005) to be approximately 79,000 cubic yards including additional drainage. Another estimate of 56,000 cubic yards was obtained based on the review of flow and TSS data at Little Falls and accounting for additional drainage area between Little Falls and Dundee Dam. In either case the mass of solids delivered is substantial and comparable to that deposited annually on the bed of the Lower Passaic River (67,000 cubic yards per year).

However, for the primary human health risk driver, 2,3,7,8-TCDD, the Upper Passaic River can be ruled out as a source of concern. Be^7 bearing sediments obtained from above Dundee Dam yield 2,3,7,8-TCDD concentrations two orders of magnitude below those observed in the surface sediments of the Lower Passaic River (Observation PR-10). Older sediments obtained from the Dundee Dam sampling locations exhibit similarly low dioxin levels. Additionally, the tetrachlorodioxins in the Upper Passaic River sediments are primarily comprised of congeners other than 2,3,7,8-TCDD, yielding a 2,3,7,8-TCDD to total TCDD ratio of less than 0.1 (Observation PR-17). Thus, solids delivered from above Dundee Dam cannot create the 2,3,7,8-TCDD concentrations observed in Lower Passaic River surface sediments. These observations unequivocally rule out the Upper Passaic River as an important source of 2,3,7,8-TCDD.

There are some contaminants, however, that occur at sufficient concentrations in Upper Passaic River sediments to represent a potentially important source. Among these are mercury, cadmium, copper, lead, PAHs, and PCBs (Observations PR-15, PR-16, PR-20 and DD-2). For the metals and low molecular weight (LMW) PCBs, the concentrations are roughly half those observed in the Lower Passaic River sediments. Since these constituents are largely transported on suspended matter, increases in concentrations on recently-deposited sediments must be due to the addition of contaminant mass. Thus, the Upper Passaic River may contribute some of these contaminants, but an additional

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important downriver source must also exist, one capable of doubling the concentration of these constituents on the solids deposited in the Lower Passaic River. Based on this observation, the Lower Passaic River source(s) must be comparable in magnitude to that of the Upper Passaic River for these contaminants. For high molecular weight (HMW) PCBs and PAHs (Observations PR-15 and PR-16), the concentrations in the Upper Passaic River are comparable to or greater than those seen in the Lower Passaic River. In these cases, the Upper Passaic River probably represents the major source.

In summary, these data are sufficient to determine that there is no major source of dioxin originating in the Upper Passaic River. However, for metals and LMW PCBs, the data are sufficient to document the occurrence of an Upper Passaic River source but also a Lower Passaic River source of comparable magnitude. For PAHs and HMW PCBs, the Upper Passaic River likely represents the major source to Lower Passaic River sediments.

Does Contamination in Recently Deposited Sediments of the Lower Passaic Originate from the Tributaries, SWOs and CSOs? Ten to twenty percent of the total upland flow to the Lower Passaic River originates with the tributaries, CSOs and SWOs. As such, they have the potential to deliver substantive contamination to the Lower Passaic River. However, due to their relatively small size, the concentrations on the solids delivered by these smaller flows would have to be substantially larger than those observed for Upper Passaic River solids, which represent the bulk of the annual solids delivery. The data available to characterize these sources do not support the existence of such concentrations for most constituents. For 2,3,7,8-TCDD in particular, measurements indicate concentrations on these external sources at least an order of magnitude below the observed surface concentrations of the Lower Passaic River (Observation PR-10). Similarly, the 2,3,7,8-TCDD to total TCDD ratio in these external sources is substantially different from that of the Lower Passaic River (Observation PR-17). On the basis of these observations alone, the tributaries, CSOs and SWOs can be dismissed as major sources of dioxin.

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For other contaminants, concentrations in these sources are often similar to those observed for the solids originating in the Upper Passaic River. Given the roughly 4:1 ratio of Upper Passaic River solids to the sum of tributary, CSO, and SWO solids, each of them would have to have concentrations 4 times greater than that of the Upper Passaic solids just to match its magnitude. If only one of the tributary, CSO or SWO sources were to be important, its concentrations would have to be 10 (or more) times greater than those of the Upper Passaic River solids. Based on the data set collected to date as part of the Lower Passaic River Remedial Investigation (RI) and the Contaminant Assessment and Reduction Project (CARP), which include limited CSO and extensive SWO sampling events, such conditions have been observed for only a small subset of the contaminants, ruling out this hypothesis for contaminants such as dioxin, PCBs, PAHs, and mercury. In these instances, the sum of tributary, CSO, and SWO loads is expected to represent less than 20 percent of the total. Only for lead, copper, and dieldrin are concentrations sufficient to yield a substantive portion of the total load.

Does Contamination in Recently Deposited Sediments of the Lower Passaic River Originate from Resuspended Legacy Sediments? In each of the hypotheses described above, the comparison between the 2,3,7,8-TCDD concentrations in the source solids and that in the surface sediments of the Lower Passaic River was enough to dismiss each hypothesis as unworkable to produce the complete suite of contaminants seen in the sediments of the Lower Passaic River. In each case the source was incapable of yielding the 2,3,7,8-TCDD concentrations observed in recently deposited sediments. The sources described above are probably important for other contaminants, but not for dioxin.

In this hypothesis, resuspension is considered as the primary source of dioxin and is also important for other contaminants. As noted in Observation PR-19, there exists a large inventory of contaminated sediments in the Lower Passaic River, resulting from the coincidence of the lack of channel maintenance and the historical chemical discharges. However, much of the historical material is characterized by concentrations much greater than those observed at the river's sediment surface. For resuspension to be a viable

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hypothesis, additional cleaner sediments are needed to dilute the contaminated sediments resuspended from the river bottom. Both the Upper Passaic River solids and Newark Bay solids can serve this role for dioxins. For other contaminants, the relative amounts of Upper Passaic River solids and Newark Bay solids are more constrained since some contaminants vary significantly between the two sources. It is precisely this set of constraints that forms the basis for the Empirical Mass Balance Model (EMBM) developed as part of the FFS.

Given the discussion above, the CSM is informed by the conclusion that resuspended sediments are blended with solids delivered by the Upper Passaic River and from Newark Bay. While Newark Bay solids are low in nearly all contaminants, the Upper Passaic River contains significant levels of PCBs and PAHs. Thus, while resuspension is responsible for all of the dioxin contamination in surface sediments (no other source can provide the concentrations observed), its role in delivering PAHs and PCBs must be tempered by the loads of these contaminants delivered by the Upper Passaic River. Note that the resuspended sediments also satisfy Observation PR-17 in that they are characterized by the high 2,3,7,8-TCDD to total TCDD ratio. Deeper sediments have ratios greater than the 0.7 observed in surface sediments. Mixing of these deeper sediments with the low-ratio dioxin mixtures observed in the Upper Passaic River and Newark Bay would yield the observed ratio in the surface sediments (see Figure 3). Replication of the surface ratio is an important observation met by the EMBM analysis.

In summary, the resuspension of historical contaminated Lower Passaic River sediments is the only hypothesis capable of reproducing both the surface concentrations of 2,3,7,8-TCDD as well as the 2,3,7,8-TCDD to total TCDD ratio observed in the surface sediments. This hypothesis can also generate the surface concentrations of all the other contaminants in the Lower Passaic River, unlike the prior hypotheses. As demonstrated by the EMBM, the sources can be combined in a linear fashion to yield the mean surface concentrations in the Lower Passaic River to within 25 percent for a broad range of contaminants.

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RISK ASSESSMENT AND REMEDIAL GOALS

The extremely contaminated surface sediments[2] present high levels of risk to human heath and the ecosystem. A risk assessment conducted for the FFS concluded that among adults consuming 40 meals per year of fish from the Lower Passaic River over 30 years, their risk of developing cancer would be one in one hundred. This risk is greater than USEPA's risk range established in the Superfund Program of one in ten thousand to one in a million. Approximately 65 percent of the human health cancer risk is associated with the presence of dioxin. Most of the remaining cancer risk (approximately 33 percent) is from PCB, while all other contaminants combined contribute approximately two percent. Accordingly, fish consumption advisories have been in place for many years due to contamination from dioxins and PCB. Similar risks are present for wildlife, although metals and pesticides cause most of the risk to fish, while dioxin and PCB cause most of the risks for animals and birds that eat fish. Table 3 shows the baseline risks presented by contaminants of potential concern (COPC) and contaminants of potential ecological concern (COPEC).

Table 3: Baseline Risks

Receptor / Endpoint		**Risk / Hazard**
Cancer Risk – Adult + Child	Fish Consumption	$1x10^{-2}$
	Crab Consumption	$2x10^{-2}$
Non-cancer Health Hazard – Adult	Fish Consumption	64
	Crab Consumption	86
Non-cancer Health Hazard - Child	Fish Consumption	99
	Crab Consumption	140
Macroinvertibrates/sediment benchmarks Hazard		1898

[2] A distinction is drawn between *surface sediments* which are defined as the bioavailable layer (usually the upper six inches) and *recently deposited sediments* which are Be^7 bearing

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Macroinvertibrates/Critical Body Residue (CBR) Hazard	1665
Fish (American eel/white perch)/CBRs Hazard	6858
Fish (mummichog)/CBRs Hazard	694
Mammal (mink)/ingestion dose modeling Hazard	341
Bird (heron)/ingestion dose modeling Hazard	48

Remedial Action Objectives (RAOs) were established to describe what the cleanup is expected to accomplish, and preliminary remediation goals (PRGs) were developed as targets for the cleanup to meet to protect human health and the environment.

The RAOs are as follows:

- Reduce cancer risks and non-cancer health hazards for people eating fish and shellfish from the Lower Passaic River by reducing the concentration of COPCs in fish and shellfish.
- Reduce the risks to ecological receptors by reducing the concentration of COPECs in fish and shellfish.
- Reduce the mass of COPCs and COPECs in sediments that are or may become bioavailable.
- Remediate the most significant mass of contaminated sediments that may be mobile (*e.g.*, erosional or unstable sediments) to prevent it from acting as a source of contaminants to the Lower Passaic River or to Newark Bay and the New York-New Jersey Harbor Estuary.

The PRGs were developed based on the risk assessment and considering background concentrations contributed to the Lower Passaic River from the Upper Passaic River above the head of tide. The comparison of the risk-based values for COPCs and COPECs to the background concentrations known from samples collected above Dundee Dam

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showed that background concentrations are higher than the risk-based values. Since the Superfund program, generally, does not clean up to concentrations below natural or anthropogenic background levels (USEPA, 2002b), background concentrations were selected as PRGs. Table 4 lists the PRGs derived from background.

Table 4: Selected PRGs

Contaminant	Background Concentration (ng/g)
Copper	80,000
Lead	140,000
Mercury[a]	720
Low Molecular Weight PAHs	8,900
High Molecular Weight PAHs	65,000
Total PCB	660
Total DDx	91
Dieldrin	4.3
Chlordane	92
2,3,7,8-TCDD	0.002

(a) All occurrences of mercury are assumed to be methylated for purposes of this evaluation.

Since background levels are above risk-based concentrations, EPA is identifying and characterizing contamination entering the Lower Passaic River from the Upper Passaic River. Working with NJDEP Site Remediation managers and making use of state and federal databases, EPA is compiling a list of facilities that have used PCBs in their manufacturing processes or have PCBs on their property. The focus is on PCB, because it is the primary risk driver that has a significant percentage of its load coming over Dundee Dam. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 104e letters have been issued for information that might identify sources into the Passaic River. In another effort, EPA is developing a trackdown and cleanup program, where screening samples would be taken from a number of CSOs and SWOs to identify sewersheds that are significant contributors of hazardous contaminants into the Passaic River. Then, those hazardous contaminants would be tracked down through the sewersheds to their sources, where they would be reduced or eliminated through a

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combination of local, state or federal legal authorities. These programs to identify and address potential sources of re-contamination will be on-going as the Source Control Early Action continues through decision-making and design phases (if appropriate).

The COPC and COPEC concentrations known to exist in the surface sediments of the lower 8 miles are much greater than these PRGs. For this reason a remedial strategy that can reduce the concentrations to at least the level of background is necessary to begin to achieve the RAOs. The evaluations of risk, development of PRGs, and estimation of future concentrations were used to evaluate the benefit of remediating areas of varying sizes. Based on the estimated risk reduction, natural recovery processes alone or the remediation of localized hot spots or even hot zones spanning a one-mile segment of the river will not achieve residual risks within the USEPA risk range of one in ten thousand to one in a million within reasonable time frames. However, remediation of the lower eight miles of the river through the Source Control Early Action will reduce the COPC and COPEC concentrations in the surface sediments over the long term to the background concentrations that are introduced to the Lower Passaic River from the Upper Passaic River. Active remediation is also predicted to reduce the human health risk by 95 to 98 percent (fish versus crab consumption), the human health non-cancer Hazard Index (HI) by 93 to 96 percent (fish versus crab consumption) for the adult receptor and 78 to 86 percent (fish versus crab consumption) for the child receptor, and the ecological hazard by 78 to 98 percent (species dependent), which meets the RAOs.

Projection of future concentrations shows that remediating the lower eight miles reaches clean-up goals for 2,3,7,8-TCDD, which is responsible for 65 percent of the human health cancer risk, 40 years faster than by natural recovery processes alone. The reduction of other COPCs and COPECs is also accelerated by the remediation of the lower eight miles. Because natural recovery processes and locally targeted remedial strategies do not appreciably reduce risk, all active remedial alternatives being evaluated in the FFS have been developed to remediate the fine-grained sediments of the lower eight miles in their entirety. It is important to note that a small-scale action targeting hot

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spots or even hot zones spanning a one-mile segment of the river would not lower the risks enough to meet risk ranges, because legacy sediments in the entire lower eight miles are actively mixing and acting as the major ongoing source of contamination.

ON-GOING WORK

A draft FFS (Malcolm Pirnie, Inc., 2007c) was released in June 2007 for review by the Remedial Options Work Group, comprised of federal and state agencies, environmental and community groups, and potentially responsible parties. Over 600 comments were received and are currently being addressed. A sampling program and additional sediment transport work are being implemented to fill in data gaps and reduce uncertainties associated with the Empirical Mass Balance. Following is a brief description of that additional work.

Additional Sampling

An additional sampling program currently in progress aims to provide additional data that will further characterize the external sources and the internal distribution of contaminants. Sources of contamination are being evaluated through analysis and assessment of solids transported in the water column of the tributaries to Lower Passaic River, recently-deposited surficial sediments, and solids from CSO and SWO systems. In addition, further information is required to characterize fine-grained sediment deposits above RM8 so that their potential future impact can be estimated with regard to possible remedial scenarios for the lower 8 miles of the river.

The field sampling activities for supplemental evaluation include the following work elements:

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Water Column Sampling on Tributaries and Upper Passaic River: Water column suspended solids are being collected above the head of tide on the Saddle River, the Second River, and the Third River, as well as at the Ackerman Avenue Bridge (RM17) near Dundee Dam on the Lower Passaic River. At each location both discrete and long-term suspended matter samples are being obtained. Long-term samples are being obtained by means of sediment traps deployed for a period of 2 to 3 weeks, integrating suspended matter transport during the deployment period.

Sediment Sampling on Tributaries, Upper Passaic River, and Lower Passaic River: Four tributaries were sampled for recently deposited sediments. For 3 of the 4 tributaries, samples were obtained above the head of tide. No samples were obtained for the Second River due to the lack of recent deposits. 24 locations between RM1 to RM15 were sampled to further characterize the recently deposited sediments of the Lower Passaic River.

Supplemental Sediment Coring Above RM8: 20 coring locations above RM8 have been occupied, three of which correspond to previous Sedflume core locations. The remainder of the samples were collected within fine-grained sediment deposits, determined from previous coring logs and the field reconnaissance probing performed at the beginning of the field activities. The samples will be used to characterize the contaminant inventories of the fine-grained sediment lenses above RM8; the top six inch interval is considered the most likely to erode during a high-flow event.

CSO/ SWO Sampling: Eight sampling locations have been identified for the CSO sampling. There will be 3 rainfall sampling events, if possible. There will be 4 to 6 locations sampled per event, if possible. Sampling locations have been identified from the observed SWO river outfalls. Further field reconnaissance has identified locations actually discharging.

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Additional Modeling

In parallel with further sampling, additional sediment transport modeling work is being performed in an attempt to reduce uncertainty associated with the EMBM analysis. Specific objectives of the modeling work include development of:

- a quantitative understanding of the spatial distribution of sediment resuspension throughout the Lower Passaic River,
- a process-based, quantitative examination of the relative contributions of source categories (*i.e.*, Upper Passaic River, tributaries, CSO/SWO, Newark Bay, internal resuspension) to solids accumulation throughout the Lower Passaic River,
- an understanding of the rate at which surface sediments mix longitudinally along the axis of the Lower Passaic River, and
- an estimate of the spatial extent of the redistribution of particles released during dredging.

The sediment transport model (ECOMSED with SEDZLJ), which was set up for the analysis of remedial alternatives in the FFS, is being used in this work. The model is being used to simulate the time period from 1995 to 2005, and is being tested against water column suspended solids data and changes in bathymetry noted between surveys conducted in the late 1990s through 2001. In order to complete the analysis within a six-month timeframe, no attempt was made to incorporate the additional data being collected as described above. Suspended solids mass loading estimates developed as part of the EMBM analysis have been used to develop model inputs for solids from the Upper Passaic River at Dundee Dam, tributaries and from CSOs/SWOs. Use of these inputs will provide consistency between the EMBM and the process-based sediment transport modeling. Downstream boundary conditions for solids are based on an analysis of data collected through Rutgers University and New York City Department of Environmental Protection's harbor survey program. Sedflume data are being analyzed to develop model

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inputs for erosion rates and critical shear stresses at fixed down-core vertical horizons.

EVALUATION BASED ON 11 RISK MANAGEMENT PRINCIPLES

The following sections of the document present an evaluation of the investigations and feasibility analyses to date with respect to a potential Source Control Early Action in the context of the 11 Risk Management Principles embodied in OSWER Directive 9285.6-08 (USEPA, 2002a).

1 CONTROL SOURCES EARLY

During the course of the Study, the sediments of the lower eight miles of the river have been identified as the major long-term source of contamination to the rest of the lower river and Newark Bay. Ample evidence of this is discussed in the Conceptual Site Model and Risk Assessment and Remedial Goals sections above.

The relative importance of various sources of contaminants to the recently deposited sediments of the Passaic River was evaluated through an EMBM that balanced sources from Newark Bay, the Upper Passaic River, tributaries, and CSO/SWOs (see Conceptual Site Model above). For dioxin, the main risk driver in the Lower Passaic River, the most significant source was the resuspension of sediment within the Lower Passaic River itself. The other sources evaluated in the EMBM contribute varying amounts of the less important COPCs and COPECs: The Upper Passaic River is the dominant source of PAH compounds to the Lower Passaic River, resuspension of legacy sediments and the Upper Passaic River contribute roughly equal proportions of PCBs to the river, the combination of resuspension and the Upper Passaic River account for the majority of the dichlorodiphenyldichloroethylene DDE and mercury contaminant burdens to the river, and the mass balance for lead indicates roughly equal contaminant contributions from all five sources (resuspension, Upper Passaic River, major tributaries, CSO/SWOs, and Newark Bay).

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Through a combination of traditional Superfund enforcement methods and an innovative trackdown program (as discussed in the "Risk Assessment and Remedial Goals" section), EPA expects to identify and address sources of hazardous contaminants that might potentially re-contaminate any remedy implemented in Source Control Early Action. Because Newark Bay receives particle-bound contamination from a variety of sources, including the Lower Passaic River, the implementation of the Source Control Early Action will effect a gradual decrease in contaminant concentrations in Newark Bay (see Risk Assessment and Remedial Goals section above).

Since there are other sources of contamination to the lower river it is appropriate to ask why the Source Control Early Action is primarily designed to control legacy contamination sources early. Remediation of the lower eight miles is being considered prior to completion of the Remedial Investigation/Feasibility Study for entire 17-mile Study Area to more quickly reduce the single largest source of contamination (and human health risk) to the Lower Passaic River (*i.e.*, the resuspension of legacy sediments). As described in detail in the Background section above, the construction of the CSM and the EMBM (Appendices A and D of the FFS; Malcolm Pirnie, Inc., 2007c) identified resuspension of legacy sediments as the largest contributor of the COPC contaminants that pose the greatest risk to human health, *i.e.,* dioxins and PCBs. The remediation of legacy sediments would significantly reduce contaminant concentrations in the Lower Passaic River as well as the contaminant loading to Newark Bay and the remainder of the New York – New Jersey Harbor Estuary.

2 INVOLVE THE COMMUNITY EARLY AND OFTEN

Numerous efforts to involve local communities along the 17-mile stretch of the Passaic River are presented in the Community Involvement Plan for the Lower Passaic River Restoration Project and the Newark Bay Study (Malcolm Pirnie, Inc., 2006a). Key elements are summarized here.

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At the beginning of the project, the structure illustrated in Figure 4 was established to keep local community groups involved. The Project Delivery Team (PDT) is an overall group composed of the six partner agencies and all interested stakeholders, including local community groups, environmental groups, potentially responsible parties, universities, municipalities and others. The PDT meets quarterly to review progress on all aspects of the project (including the 17-Mile Study and Early Action). Six workgroups were formed to provide a forum for subject experts and particularly interested stakeholders to have in-depth technical discussions on specific topics. The workgroups meet whenever products, such as sampling plans or the Focused Feasibility Study, are developed, to provide input, review drafts or come to consensus on comments. The "Remedial Options Workgroup" has focused on development of the FFS.

The partner agencies have been active participants in local community events as a way to spread information about the project. Events include providing information during a regatta in 2005 and making presentations at two symposia (2004 and 2006) held at a local university. EPA has also pursued partnerships with local environmental and civic organizations to help inform communities about project events. These organizations have posted meeting announcements, press releases and project information on their websites. They are able to reach out farther than the partner agencies could have done alone.

The public website for the project, www.ourPassaic.org, enables interested parties to obtain background information, meeting notices and other project-specific information. In addition, the website offers the opportunity for local organizations and individuals to sign up for a ListServ, which delivers project announcements directly to its subscribers via e-mail. Hard copies of key documents are available in local libraries, which serve as repositories.

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3 COORDINATE WITH STATES, LOCAL GOVERNMENTS, TRIBES, AND NATURAL RESOURCE TRUSTEES

All six partner agencies have been involved in the various components of the project, including identification of Applicable or Relevant and Appropriate Requirements (ARARs) and development of planning documents. For the Early Action FFS in particular, it has been important for all six agencies to review drafts of the document before public release, to ensure general agreement with the approach. For the 17-Mile Study, all six agencies have reviewed and commented on CPG sampling plans to ensure that data collected would be of maximum use to CERCLA (Superfund and Natural Resource Damage Assessment [NRDA] where possible) and Water Resources Development Act (WRDA) studies.

To oversee full coordination of the 17-Mile Study and Early Action, an Executive Committee was formed composed of high level managers (equivalent to USEPA's Regional Administrator) from the six partner agencies. The Executive Committee meets quarterly to discuss progress and resolve policy issues. At the staff level, all six partner agencies are active participants in the PDT and workgroups described in Section 2 and Figure 4. The six partner agencies also conduct monthly agency-only meetings and calls to discuss implementation issues. A web site ("PREmis") accessible only by the six partner agencies was established to facilitate sharing of draft documents, sampling results and background information.

Outreach targeted specifically at municipalities along the Lower Passaic River has been important. Starting in 2004, every mayor's office was offered a briefing on the project and, to date, four municipalities (Rutherford, Kearny, Harrison and Newark) have responded and been visited. Two municipalities' workshops (in April and July 2007) were held to discuss revitalizing the river in conjunction with the 17-mile Study and Early Action. Each workshop was well attended by municipal officials and community groups.

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Municipalities had a direct influence on the development of the remedial alternatives for the FFS. Specifically, the State of New Jersey prepared a memorandum presenting recommendations for future navigational use of the channel (Appendix F of the FFS; Malcolm Pirnie, Inc., 2007c), which was based on surveys of municipal planning officials and review of municipal master plans.

4 DEVELOP AND REFINE A CONCEPTUAL SITE MODEL THAT CONSIDERS SEDIMENT STABILITY

A CSM [Malcolm Pirnie, Inc., 2007a] was developed for the Study that includes consideration of sediment stability. The CSM was developed in 2003 based on available geochemical and modeling work, and has been revised periodically to incorporate new data (Malcolm Pirnie, Inc., 2005a and 2006c). Human health and ecological risk assessment CSMs are presented in Appendix C of the FFS (Malcolm Pirnie, Inc., 2007c).

Sediment stability has been investigated in several components of the Study, including the bathymetric analysis and dated sediment core analysis (both discussed in Malcolm Pirnie, Inc., 2006c and Malcolm Pirnie, Inc., 2007a), Sedflume analysis (presented in Borrowman *et al*., 2006), and sediment transport and modeling efforts (Appendix G of the FFS; Malcolm Pirnie, Inc., 2007c).

The Sedflume analysis consisted of erodibility experiments performed on 28 sediment cores from the Lower Passaic River in May-June 2005 (Borrowman *et al*., 2006). The purpose of the Sedflume analysis was to measure the variability of erosion rates with depth of relatively undisturbed sediment core samples extracted from the site. The analysis indicated that sediment cores from some locations within the Lower Passaic River showed resistance to erosion (with approximately 30 to 40 percent fines and measured erosion rates of less than 1×10^{-2} centimeters per second for a 3.2 Pascal shear stress), while cores from other locations within the river were very susceptible to erosion

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at low shear stress. Noteworthy heterogeneity was observed between replicate cores from the same sampling location.

One of the earliest observations made in the development of the CSM focused on the rapid rate of sediment accumulation in the Lower Passaic River coupled with the fact that the surface sediments remained contaminated many years after the known major sources of dioxin were eliminated. If the Lower Passaic River was truly accumulating sediments rapidly with little reworking of the sediment bed, the dioxin contamination should be rapidly declining. The 1995 sediment coring survey and the dated sediment cores from 2005 unambiguously documented that this was not occurring (see Figure 5).

5 USE AN ITERATIVE APPROACH IN A RISK-BASED FRAMEWORK

An iterative approach has been used throughout the Study with respect to the assessment of available data and the development of new data. Each effort builds on previous efforts, and each component of the Study aims to derive as much information out of new and existing data as possible. Geochemical efforts include the Technical Memorandum: Preliminary Geochemical Evaluation (Malcolm Pirnie, Inc., 2005b), which was further developed into the Draft Geochemical Evaluation (Step 2) (Malcolm Pirnie, Inc., 2006c). The first geochemical evaluation document relied on previous investigations and limited new data, but was instrumental in beginning to define the histories of contaminants, such as discerning that dioxin predates PCBs but not PAHs. The second geochemical evaluation document used data collected in late 2005 and 2006 and refined the contaminant chronology and distribution; it showed that concentrations of PAHs increase with depth through the sediment column. The second document also included a preliminary mass balance of dioxin and mercury for Newark Bay. This mass balance showed the Passaic River to be a significant source of dioxin to Newark Bay and that there was a separate uncharacterized source for mercury. Both of these documents were

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used in developing and refining the CSM and ultimately resulted in developing the EMBM that supported the FFS.

Other components of the Study, including the Pathways Analysis Report (Battelle, 2005), the Baseline Ecological Risk Assessment (BERA) Workshop (Battelle, 2006), and the Risk Assessment performed for the FFS (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007c) have also built upon each other, further refining the characterization of ecological risks and exposure pathways with each new effort. The 17-mile study will incorporate a more detailed risk assessment, which will build upon the conservative estimates for current and future risk levels generated in the streamlined FFS Risk Assessment.

Sampling efforts have also employed an iterative approach. Bathymetric surveys performed in the fall of 2004 (as well as previous field investigation studies) aided in the development of the intensive geophysical and geotechnical sampling programs in the spring of 2005. Sediment coring and water column investigations conducted from summer 2005 through early 2006 then built upon the geophysical and geotechnical studies, as well as on earlier coring studies conducted by TSI, partner agencies, and others. A sampling plan for biological characterization efforts (Malcolm Pirnie, Inc., 2006b; anticipated to be implemented by the CPG) likewise builds upon previous biological sampling programs conducted by Tierra Solutions, Inc., as well as an Environmental Resource Inventory and Ecological Functional Analysis performed by Earth Tech, Inc. (Malcolm Pirnie, Inc., 2006b) for USACE's WRDA component of the 17-mile Study. Field investigations in 2004 also provided data for the development of the Environmental Dredging Pilot Study and ex-situ sediment stabilization demonstration in late 2005 (Malcolm Pirnie, Inc., 2007b). The Environmental Dredging Pilot Study evaluated dredge performance, productivity, and sediment resuspension associated with an Environmental Dredging Demonstration and assessed the treatability and beneficial use of contaminated sediment through a Sediment Decontamination Technology Demonstration.

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In addition to the iterative approach used in field investigation programs and data analysis efforts, the Source Control Early Action FFS builds upon available data to address the ongoing release of legacy sediments through erosion and resuspension, while the full RI/FS for the 17-mile Study is ongoing. Although this is a complex site, the Source Control Early Action contemplates the need to take action quickly to reduce a 10^{-2} human health risk (and comparably high ecological risk) that was found to exist at the site by ongoing work on the 17-mile Study and to control the ongoing spread of contamination from the Passaic River into Newark Bay. The development of the FFS represents an iterative approach to the development of remedial options for the Lower Passaic River.

6 CAREFULLY EVALUATE THE ASSUMPTIONS AND UNCERTAINTIES ASSOCIATED WITH SITE CHARACTERIZATION DATA AND SITE MODELS

Key documents leading to the development of the FFS (Malcolm Pirnie, Inc., 2007c) included detailed evaluations of assumptions and uncertainties. These evaluations were performed in the CSM (Malcolm Pirnie, Inc., 2007a) and the EMBM (Appendix D of the FFS; Malcolm Pirnie, Inc. 2007c), including an identification of data gaps. In addition, the Cap Erosion and Flood Modeling (Appendix G of the FFS; Malcolm Pirnie, Inc., 2007c) includes a detailed discussion of important assumptions and uncertainties in the modeling process.

Uncertainties in the CSM, EMBM, Cap Erosion and Flood Modeling, and Risk Assessment are summarized below.

CSM: Uncertainties in the CSM are partially due to data gaps. For example, while bathymetric surveys, side scan surveys and radiodated sediment cores are available to characterize nearly all 17 miles of the lower river, sampling to characterize local contaminant concentrations in sediments over the past 10 years (*i.e.,* lateral variability)

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was focused on the three miles on either side of 80-120 Lister Avenue (RM1 to RM7) due to study boundaries set in the original Administrative Order on Consent of 1994. As a result, limited data on the lateral extent of contamination exist for areas upriver of RM7 and between RM0 and RM1. A similar data gap exists with respect to the vertical extent of contamination, since many of the cores collected under the Administrative Order did not extend through the entire contaminated sediment sequence. Water column and hydrodynamic data are also incomplete for the Lower Passaic River. For example, not all tributaries were directly sampled for all parameters of interest and values had to be approximated from other tributary data. [Refer to the CSM (Malcolm Pirnie, Inc., 2007a) for a detailed list of data gaps associated with the sediment beds and water column.] Other uncertainties involve the appropriate linkage of the human health and ecological exposure pathways and receptors (Battelle, 2005) to construct the CSM.

Evidence assembled for the construction of the CSM is strongly indicative of a single source of dioxin to the Lower Passaic River, based on both the uniqueness of the dioxin signature relative to the rest of the entire harbor as well as the steady although slow decline in dioxin concentrations for 25 years after the cessation of operations at the Lister Avenue site, as documented by 5 dated sediment cores. However, the dated sediment cores also suggest a recent dioxin release event, probably located above RM5 of the Lower Passaic River. The data from this period are currently undergoing close scrutiny and the following interpretation should be considered preliminary.

Analytical data from three of the dated cores from RM7.8 to RM12.6 all show a 2,3,7,8-TCDD peak in sediments deposited post-1995. This increase is not accompanied by an increase in any other contaminant, as might be expected if the increase were due to the re-release of older sediments. Two of the cores show a tripling of the sediment concentration during this peak followed by a rapid return to levels close to those prior to the release event (*i.e.,* 300 picograms/gram [pg/g]). The chronologies of the two more highly resolved cores place this event sometime between 1999 and 2003.

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The nature of the peak observed in the high resolution cores suggests that there may have been a point-release of dioxin, which provided a pulse of the contaminant to the Upper Passaic River. The current analysis will examine these peak layers for dioxin or other contaminant characteristics that may distinguish this release from the historical dioxin discharges. However, it must be noted that such an event is not seen at other times in the previous 25 years in the dated cores and that the calculated mass release represented by the peak is orders of magnitude less than the historical discharges. This observation does not significantly affect the CSM as presented, but will be studied further to clearly document its ramifications.

EMBM: Sources of uncertainty in the EMBM calculations arise primarily from those source terms that lack direct characterization. For sources characterized by Be^7 bearing core tops (Upper Passaic River, Newark Bay and the Lower Passaic River surface sediments) or direct measurements (SWOs), the uncertainty is primarily limited to the analytical variation, which is generally small. For the tributaries and CSO discharges, the estimates of their contributions are more uncertain since the direct measurements are more limited or approximated from other data sources.

To quantify the uncertainties based on the data available, the range and variability in the measured concentrations used in the EMBM (both source profiles and receptor concentrations) were incorporated in a one-dimensional Monte Carlo analysis, which was used to estimate the range of solids contributions to the Lower Passaic River (see Figure 6). In this approach, a concentration distribution was specified for each contaminant in each source term based on the observed values, and the mass balance calculations were repeated 5000 times using randomly selected concentrations for the sources and receptor. In general, the Monte Carlo analysis results indicated that resuspension of legacy sediments varies from 5 to 15 percent of the total solids contribution, the solids contribution from the Upper Passaic River is similar to that from Newark Bay (each contributing approximately 40 percent), and the solids contribution from major tributaries is similar to that from CSO/SWOs (each contributing approximately 5 percent). These

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estimates were consistent with those derived from the deterministic formulation of the EMBM. Refer to Appendix D of the FFS (Malcolm Pirnie, Inc., 2007c) for additional discussion on uncertainty in the EMBM.

The additional sampling and modeling work described in the "On-Going Work" section are being undertaken to address data gaps and reduce uncertainties in the EMBM.

Cap Erosion and Flood Modeling: One uncertainty associated with the Cap Erosion Modeling has been addressed by making a conservative assumption in the analysis. Specifically, the modeling analysis does not include the consideration of any sands (non-cohesive) and cohesive soils that might enter the Lower Passaic River at the Dundee Dam or from rainfall-related runoff from the drainage area below the Dundee Dam which would serve to provide additional protection for the cap. Hence, the Cap Erosion Modeling results (Appendix G of the FFS; Malcolm Pirnie, Inc., 2007c) may be considered to be conservative in nature. A separate sensitivity analysis was performed as part of the Flood Modeling (Appendix G of the FFS; Malcolm Pirnie, Inc., 2007c) to account for shoreline and land elevation uncertainties of +/- 1 foot. The results suggest that the flooding area during the 100- and 500-year floods would increase by as much as 62 and 32 percent, respectively, when the land elevation input into the model was reduced by 1 foot (compared to the original land elevation used in the analysis).

Risk Assessment: Some uncertainty is inherent in the processes used to conduct predictive human health and ecological risk assessments, as discussed in the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007c) and briefly summarized below. Generally, reliance on USEPA guidance, guidelines, and policies should limit or reduce uncertainty.

Two primary sources of uncertainty are noted and discussed: model uncertainty [i.e., the methods/models used to calculate exposure point concentrations (EPCs) and risk] and parameter uncertainty (i.e., the model input parameter exposure variables). Key

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uncertainties associated with development of future EPCs for the various actions under consideration include:

- certain assumptions in the empirical mass balance model,
- development and application of the bioaccumulation factors,
- estimation of 95% upper confidence limit EPCs, and
- the lack of evaluation of dioxin and PCB congener residues in avian eggs.

Key parameter uncertainties are discussed below.

Human Health Risk Assessment

The discussion of parameter uncertainty is organized according to the four-step process used to conduct the assessment (i.e., hazard identification, exposure assessment, toxicity assessment, and risk characterization) as summarized in Table 5. The source of parameter uncertainty is noted, the associated uncertainty is described, and the potential impact on the calculated risks is assessed. Key uncertainties include:

- identification of the COPCs,
- double-counting PCB concentrations and PCB-related risks,
- estimating methyl mercury-related risks based on data for total mercury,
- the EPCs, potential receptors, and exposure assumptions evaluated in the assessment,
- the availability and limitations of the toxicity data for the COPCs, and
- the procedures used to calculate or aggregate risks.

Since conservative assumptions were employed throughout the assessment, overall, the risk assessment tended to overestimate human health risks.

Ecological Risk Assessment

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The discussion of uncertainty is also organized according to the multi-step process used to conduct the assessment (i.e., problem formulation, exposure assessment, effects assessment, and risk characterization) as summarized in Table 6. The source of parameter uncertainty is noted, the associated uncertainty is described, and the potential impact on the calculated risks is assessed. Key uncertainties include:

- identification of contaminants of potential ecological concern (COPECs),
- evaluation of only some potentially complete exposure pathways, ecological receptor categories, or life stages,
- the EPCs, potential receptors, and exposure assumptions evaluated in the assessment,
- the availability and limitations of the toxicity data for the COPECs, and
- the procedures used to calculate or aggregate risk.

Although conservative assumptions were employed throughout the assessment, overall, the risk assessment tended to underestimate ecological hazards because of the limited focus of the analysis.

Several uncertainty considerations were raised as part of the review of the draft FFS and are discussed below:

Upstream Source Identification and Control: As noted in the discussion in Section 4 above, neither the Upper Passaic River nor any external source are important sources of dioxin to the Lower Passaic River. With respect to PCBs, these external sources are responsible for roughly half of the annual load. Thus, for human cancer risk issues, the uncertainty associated with the upstream source is relatively unimportant, since upstream sources account for half of the PCB load which in turn is responsible for less than 15 percent of the total carcinogenic risk. For non-cancer impacts, PCB are the dominant contaminant and the upstream source uncertainty at Dundee Dam is more important. To address this, EPA has obtained and is currently analyzing a dated sediment core from above Dundee Dam. Additionally, several core tops have recently been obtained to

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further define current loads from above Dundee Dam as well as from the Saddle and Third River. A program to obtain direct measurements of suspended solids from all four tributaries is ongoing as well. Through a combination of traditional Superfund enforcement methods and an innovative trackdown program, EPA expects to identify and address sources of hazardous contaminants that might re-contaminate any remedy implemented in Source Control Early Action. Given the scale of the remedial efforts for the Lower Passaic River sediments, it is likely that such a trackdown program will have been completed prior to completion of the downriver remediation.

Characterization of Lower Eight Miles of the River/Distribution of Contaminants:
The current data set to characterize the sediments of the Lower Passaic River is listed below. While additional sediment data are always valuable, the data set is sufficient to understand the history of contamination and the current fate and transport of the COPCs and COPECs.

- 62 cores collected between RM0 and RM7 from 1991 to 1993

- 104 cores obtained in 1995 between RM1 and RM7. These cores consistently characterized the 0 to 6 inch sediment interval although many do not penetrate the entire thickness of contamination.

- 10 cores collected in 2005 extending through the entire thickness of contamination at some of the hottest locations previously observed.

- 3 dated sediment cores and 2 Be^7 bearing core tops for dioxins, PCBs and pesticides; 5 dated sediment cores for metals and PAHs; all collected in 2005. Note these cores extend from RM1.4 to RM12.6 and examine the entire thickness of fine-grained sediment at each location. Because they were successfully dated and contained Be^7 in their uppermost layer, they can be used to characterize the last 60 years of suspended matter transport and associated contaminant transport throughout the entire river.

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- 20 Be^7 bearing core tops obtained from RM1 to RM15 collected in 2007. These core tops (0-2 cm) have been analyzed for metals and characterize the degree of homogeneity in recently deposited sediments. Eight of these core tops is being analyzed for dioxins, pesticides, PCBs and PAHs to provide similar information for these organics.

Modeling Uncertainty: Any model of the Lower Passaic River must be able to address the direct observations of the river, summarized in Table 1. Note that these observations are independent of any model framework. To date the EMBM is consistent with these observations but can be modified if needed. Any numerical modeling completed for the river needs to be consistent with these observations as well. Both the EMBM and numerical model will be updated with the new field data collected in January 2008 to reduce the modeling uncertainty in the final version of the FFS.

Although the various data analysis and modeling efforts associated with the Lower Passaic River Restoration Project require that inferences be made and uncertainties be considered, these inferences have been derived from a thorough and comprehensive understanding of the site through the CSM, which was built upon detailed geochemical data evaluations and the assimilation of various data sources. Inferences have been conservative whenever possible and are rationally derived from the CSM. Inferences have been coherent and consistent and, particularly in the EMBM, they work together to provide a more complete understanding of site processes and characteristics.

7 SELECT SITE-SPECIFIC, PROJECT-SPECIFIC, AND SEDIMENT-SPECIFIC RISK MANAGEMENT APPROACHES THAT WILL ACHIEVE RISK-BASED GOALS

The selection of site-specific, project-specific, and sediment-specific risk management approaches is reflected in the development of the active remedial alternatives presented in the FFS (Malcolm Pirnie, Inc., 2007c). The alternatives were developed without a

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presumption of a specific remedy. Based on the finding of risks above the risk range for both human health cancer and non-cancer and ecological hazards, the FFS evaluated three approaches: natural recovery processes; remedial action in a small area of the Lower Passaic River; and remedial action in the entire area of the lower eight miles of the River. Risk assessment results showed that it was necessary to address the entire eight-mile stretch to achieve the required risk reduction within a reasonably foreseeable time frame. The active remedial alternatives presented in the FFS were developed to address contamination in this eight-mile stretch.

The elements used to construct the remedial alternatives were developed in consideration of site-specific, project-specific, and sediment-specific aspects. A site-specific hydrodynamic and sediment transport model was used to determine whether the placement of an engineered cap would result in additional flooding impact to the area surrounding the Lower Passaic River. The understanding of the interplay between deposition and discharges, which led to thick sequences of contaminated fine-grained sediment built up over native, less-contaminated sands, was used to select sediment-specific approaches for covering the dredged surface. Finally, the input of a diverse group of project-specific stakeholders was utilized at various points in the development of the remedy.

DESCRIPTION OF REMEDIAL ALTERNATIVES

In addition to the No Action alternative, eight active remedial alternatives are being evaluated for the final FFS:

- Alternative 1 – Dredging with confined disposal facility (CDF) Disposal
- Alternative 2 – Dredging with CDF Disposal and Partial Decontamination
- Alternative 3 – Dredging with Off-site Treatment and Disposal
- Alternative 4 – Dredging with Full Decontamination
- Alternative 5 – Capping with Pre-dredging, CDF Disposal

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- Alternative 6 – Capping with Pre-dredging, CDF Disposal and Partial Decontamination
- Alternative 7 – Capping with Pre-dredging, Off-site Treatment and Disposal
- Alternative 8 – Capping with Pre-dredging, Full Decontamination

The active remedial alternatives target the fine-grained sediment present in the lower eight miles by dredging or capping. Dredging alternatives (*i.e.*, Alternatives 1 through 4) involve the removal of fine-grained sediment from the lower eight miles followed by backfilling. Capping alternatives (*i.e.*, Alternative 5 through 8) incorporate limited dredging such that no net increase in flooded acreage is achieved after placement of an engineered cap in the lower eight miles. Based on recent discussions with the six partner agencies and the City of Newark, a 30 feet mean low water deep navigation channel from RM0 to RM1.9 is incorporated into all eight active remedial alternatives to fulfill the reasonably anticipated future use for that stretch of the river. Dredged material management options include placement in a near shore CDF, placement of some material in a near shore CDF with onsite or regional thermal treatment of the remaining material, transportation and offsite treatment and disposal, and full treatment at a regional processing facility. After construction, each active remedial alternative relies on institutional controls, natural recovery processes, and five-year reviews as required under CERCLA.

These alternatives are newly revised from the set presented in the draft FFS (Malcolm Pirnie, Inc., 2007c), based on comments received from agency and stakeholder reviewers. Therefore, work is on-going to revise cost estimates, volume estimates, short-term impacts of implementation, and long-term risk reductions resulting from remediation. To provide some idea of the magnitude of volumes and costs, the range of volumes for the old alternatives in the draft FFS is 1.1 million cubic yards to 11.0 million cubic yards, and the range of costs is $0.9 billion to $2.3 billion.

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While the Source Control Early Action presented in the FFS addresses the contaminated sediments of the lower eight miles of the Passaic River, a separate source control action is necessary above Dundee Dam to identify and reduce or eliminate background sources that pose unacceptable risks. Through a combination of traditional Superfund enforcement methods and an innovative trackdown program, USEPA expects to identify and address sources of hazardous contaminants that might potentially re-contaminate any remedy implemented in Source Control Early Action.

8 ENSURE THAT SEDIMENT CLEANUP LEVELS ARE CLEARLY TIED TO RISK MANAGEMENT GOALS

PRGs provide long-term targets to use during analysis and selection of remedial alternatives. Ideally, such goals, if achieved, should both comply with ARARs and result in residual risks that satisfy the National Contingency Plan (NCP) requirements for the protection of human health and the environment.

During the evaluation and development of PRGs, several human health and ecological risk-based concentration thresholds were considered (see Risk Assessment and Remedial Goals above). The human health PRGs were developed consistent with the U.S. EPA Risk Assessment Guidance for Superfund (RAGS) Part B (USEPA, 1991) and based on the results of the human health risk assessment presented in Appendix C for the FFS (Malcolm Pirnie, Inc., 2007c). The PRGs were developed for the adult angler who consumes fish or crabs from the Lower Passaic River and are summarized in Tables. Table 7 provides the fish concentration and Table 8 provides the associated sediment concentration. For the analysis, the point of departure for cancer risks was calculated at 10-6 (one in a million) and for non-cancer health hazards the point of departure was an HI = 1. The calculated PRGs assume the adult ingests 40 eight ounce fish meals per year for 24 years Appendix C of the FFS (Malcolm Pirnie, Inc., 2007c). The calculated PRGs for ingestion of crab were comparable to fish ingestion based on the slightly lower

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ingestion rate for crabs. Interim values assuming lower rates of consumption (*i.e.*, 1 meal/year, 2 meals/year, 6 meals/year, and 12 meals/year) were also calculated to provide concentrations where fish advisories established, under the Institutional Controls, can be relaxed.

Separate PRGs were calculated from toxicity to ecological receptors including benthic organisms and wildlife. Ecological PRGs were developed for copper, lead, mercury, LPAH, HPAH, total PCBs, total DDT (the sum of dichlorodiphenyldichloroethane [DDD], DDE, and dichlorodiphenyltrichloroethane [DDT] isomers), dieldrin, tetrachlorodibenzodioxin (TCDD) TEQ as dioxin/furans, and TCDD toxic equivalent quotient (TEQ) as PCBs. Sediment PRGs were developed for benthic organisms (including bivalves and crabs) and for estuarine-dependent wildlife[3]. It was assumed that the PRGs developed for these two categories of receptors will be sufficiently protective of fish species as well. Sediment concentrations protective of benthic infauna exposed directly to various constituents were derived for marine and estuarine habitats by Long *et al*. (1995). These values, termed Effects Range Low (ER-L), represent the low end of a range of levels at which adverse effects have been observed in compiled studies. Wildlife-protective sediment concentrations for bioaccumulative COPECs were calculated with the same exposure dose equations as used in the ERA. The otter (*Lutra canadensis*) and belted kingfisher (*Ceryle alcyon*) were selected as the model receptors due to their relatively large dietary exposures to sediment-associated chemicals that can bioaccumulate in biological tissue. Table 9 presents the ecological PRGs for the selected sediment COPECs for each category of receptor considered in the ERA. The overall ecological PRG is the lower of the two values.

[3] Sediment PRGs for PAHs were only derived for the benthos as these compounds are not anticipated to bioaccumulate in the estuarine food web (see Appendix C of the FFS; Malcolm Pirnie, Inc., 2007c) to levels that would pose a threat to wildlife receptors.

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The toxicity data utilized in the residue-based analysis of fish tissue chemistry (*i.e.*, CBRs) in the FFS (Malcolm Pirnie, Inc., 2007c) were selected as PRGs for the fish tissue medium along with back-calculated wildlife-protective values for fish tissue. Rather than deriving PRGs for TCDD using the above approach, sediment concentrations protective of piscivorous mammals (2.5 pg/g or parts per trillion) and birds (21 pg/g) derived by USEPA (1993) were used. The lower of these values was selected as the wildlife PRG value for fish tissue. The fish tissue PRGs presented in Table 10 include results of the residue-based (fish) and dose-based (wildlife) analyses conducted as part of the ERA.

9 MAXIMIZE THE EFFECTIVENESS OF INSTITUTIONAL CONTROLS AND RECOGNIZE THEIR LIMITATIONS

Institutional controls to be implemented after the Source Control Early Action focus on use restrictions on the waterway. Existing fish consumption advisories will remain in effect and will be gradually relaxed according to risk thresholds as sediment and fish tissue concentrations improve over the long-term. [Refer to Section 2.4 "Development of Preliminary Remediation Goals" of the FFS (Malcolm Pirnie, Inc., 2007c) and Appendix B of the FFS for PRGs for contaminants that tend to bioaccumulate in fish, such as dioxin, PCBs, and mercury.] However, fish consumption advisories have limitations in their effectiveness. Although fish consumption advisories are currently in place for the Lower Passaic River, NJDEP surveys of anglers along the river have found that a considerable proportion of the group continues to consume fish and crab above the "eat none" advisory; this consumption poses a risk to these individuals. As an institutional control, coordination between the NJDEP and USEPA regarding the issuance of fish consumption advisories will be necessary. Also, it will be necessary to supplement existing NJDEP outreach programs to inform the community regarding the advisories.

In addition to fish consumption advisories, waterway use restrictions will include restrictions on dredging to create additional berths after the implementation of the Source

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Control Early Action. After implementation of the remedy, there will likely be stringent restrictions on dredging capped portions of the river because of the potential for enhanced recontamination of the capped surface over a large area due to resuspension of contaminated sediments from below the cap and subsequent tidal mixing. Therefore, if a proposed berth area is identified in a capped area, the berth area would need to be dredged in such a way as to minimize or avoid resuspension of contaminated sediments. (This may be accomplished by completely surrounding the area to be dredged with sheet pile; however, the installation of sheet pile may create secondary effects like restricting river flow and impacting river flooding, as well as increased cap scour adjacent to the area to be dredged. An evaluation of these secondary effects would be required prior to dredging.) In addition, replacement of the engineered cap in the new berth area would be required.

Like other institutional controls, placing restrictions on dredging portions of the river that have been capped has its limitations. Controls on post-remediation dredging to minimize resuspension of contaminated sediments still incorporate some risk of recontamination of adjacent areas.

10 DESIGN REMEDIES TO MINIMIZE SHORT-TERM RISKS WHILE ACHIEVING LONG-TERM PROTECTION

As part of the draft FFS, the short-term risks associated with each of the active remedial alternatives were evaluated and compared. [Refer to Section 5.2.5 "Short-Term Effectiveness" in the FFS (Malcolm Pirnie, Inc., 2007c) and Appendix C of the FFS for a summary of these evaluations.] The development and evaluation of remedial alternatives considered the potential short-term impacts and long-term goals; however, there are tradeoffs when considering short-term and long-term impacts. For example, the option to dredge contaminated sediments was not rejected simply because dredging will cause some resuspension of particle-bound contamination. Since sediment resuspension is

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currently ongoing as a natural process, and the ultimate goal of the Source Control Early Action is to drastically reduce erosion and resuspension of legacy sediments as a source of contamination to the river, the additional short-term potential resuspension associated with dredging operations was not the only deciding factor when evaluating the long term protection achieved by active remedial alternatives involving dredging. Work to be done as part of the final FFS will consider the likelihood and seriousness of various possible mechanisms for short-term impacts, the tools available to characterize them, and the appropriate approaches to make quantitative or semi-quantitative estimates of the impacts where feasible. For example, evaluation of dredge pilot resuspension data and the use of sediment transport modeling runs based on the on-going effort described under the section "Additional Modeling" above will be brought to bear for this purpose.

All aspects of remedy design and implementation will be developed in consideration of Health and Safety Plans generated to provide protection and reduce risks for workers and surrounding community. Community outreach programs would be performed to understand the communities' health concerns during the project, and coordination with community members would be undertaken to identify actions needed to protect their health and safety. Work areas in the river would be isolated (access-restricted) for safety reasons. In addition, selected aspects of the remedy design which may be incorporated to reduce short-term risks include:

- Construction and Operation of a Support Area: The site for the support area is assumed to have riverfront access, and access to these areas would be restricted to authorized personnel. An ambient air monitoring program could be implemented where required to provide protection for the surrounding community. As the land use near the Lower Passaic River is primarily industrial, minimal additional environmental impact is likely to arise from the construction of the support area.

- Dredging: Dredging operations (including dredging and transportation of dredged material) will inevitably involve short-term impacts associated with resuspension of

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sediment. However, installation of structures to isolate areas of dredging would also likely result in some degree of resuspension, and would result in a longer timeframe necessary to achieve RAOs. For these reasons, the utilization of best management practices and specialized technology is more likely to achieve a more favorable balance between short-term impact and long-term risk reduction than dredging using containment structures.

- Capping: Capping operations may be less disruptive of local communities than dredging (USEPA, 2005), and would result in less potential for noise disturbances and air pollution than dredging operations. Environmental impacts during capping would be mitigated by using cap placement techniques that avoid resuspension to the extent practicable, but a temporary loss of habitat would be an inevitable impact associated with the placement of cap material.

- CDF Construction and Operation: Activities associated with capping and CDF construction would also result in a temporary loss of habitat for aquatic and benthic organisms. However, the use of a CDF for dredged material storage and disposal would likely result in a shorter timeframe for achievement of RAOs, as the potential for delay and issues with throughput and capacity associated with other transport and disposal methods would be eliminated.

- Thermal Treatment: Thermal destruction was included in the remedy development because it is one of the only technologies proven as effective in treating the organic COPCs and COPECs (*i.e.*, Polychlorinated Dibenzodioxins/Furans [PCDD/F], PCB, and PAH) detected in the sediment of the lower eight miles of the river. Air emissions generated by a thermal destruction facility would be strictly monitored and controlled to ensure protection of the surrounding community and air quality.

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11 MONITOR DURING AND AFTER SEDIMENT REMEDIATION TO ASSESS AND DOCUMENT REMEDY EFFECTIVENESS

Monitoring is incorporated into the Source Control Early Action, both during implementation of the remedy and after implementation has been completed. Both the effort and the estimated costs for monitoring have been evaluated for the remedy and are presented in the FFS (Malcolm Pirnie, Inc., 2007c). Monitoring includes chemical analyses to characterize sediments and the water column, as well as biological tissue. Table 11 summarizes the annual monitoring activities that are incorporated into the Source Control Early Action. In addition to these activities, the Source Control Early Action includes five-year remedy reviews as required under CERCLA Section 121(c). As discussed above, the Source Control Early Action will be implemented while the 17-mile Study continues. The data gathered during this time from the ongoing study will provide the baseline monitoring against which future monitoring can be compared.

Table 11: Source Control Early Action Annual Monitoring Program

Monitoring Type	Monitoring Frequency	Monitoring Parameters
Surface Sediment Sampling	400 samples per year; 5 samples taken at transects of 0.1 river mile	• Geotechnical parameters (grain size, percent moisture, total organic carbon [TOC]) • Target Analyte List metals • Cyanide • Dioxins
Water Column Sampling	35 samples per year; 2 samples taken for 2 tidal cycles per river mile	• Total suspended solids • TOC
Groundwater Sampling	144 samples per year; 12 wells sampled per month	• Parameters to be determined

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Biological Monitoring	One monitoring program per year	• Habitat delineation • Terrestrial vegetation • Avian community • Aquatic community • Aquatic vegetation (SAV) • Fish community • Benthic invertebrates • Biological tissue-residual • Toxicity testing

In addition to the monitoring activities discussed above, remedy effectiveness would also be maintained through cap maintenance efforts, which would be required in perpetuity.

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ACRONYMS

2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzodioxin
ARAR	Applicable or Relevant and Appropriate Requirement
ATSDR	Agency for Toxic Substance and Disease Registry
Be^7	Beryllium-7
BERA	Baseline Ecological Risk Assessment
CARP	Contaminant Assessment and Reduction Project
CBRs	Critical Body Residue
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	Contaminants of Potential Concern
COPEC	Contaminants of Potential Ecological Concern
CPG	Cooperating Parties Group
CSM	Conceptual Site Model
CSO	Combined Sewer Overflow
CSTAG	Contaminated Sediment Technical Advisory Group
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
the Study	Lower Passaic River Restoration Project
Total DDT	Sum of DDD, DDE, and DDT isomers
EMBM	Empirical Mass Balance Model
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ER-L	Effects Range-Low
FFS	Focused Feasibility Study

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HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW	High Molecular Weight
LMW	Low Molecular Weight
mg/kg	milligram per kilogram
mg/kg-day	milligram per kilogram per day
mg/L	milligram per liter
NA	Not Available
NCP	National Contingency Plan
ND	Not Determined
NRDA	Natural Resource Damage Assessment
ng/g	nanogram per gram
ng/kg	nanogram per kilogram
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDD/F	Polychlorinated Dibenzodioxins/Furans
PDT	Project Delivery Team
PRG	Preliminary Remediation Goal
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RfD	Oral Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	River Mile
SWO	Storm Water Outfall

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TCDD	Tetrachloridibenzodioxin
TEQ	Toxic Equivalent Quotient
TOC	Total Organic Carbon
TSI	Tierra Solutions, Inc.
µg/g	microgram per gram
µg/kg	microgram per kilogram
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WRDA	Water Resources Development Act

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FIGURES

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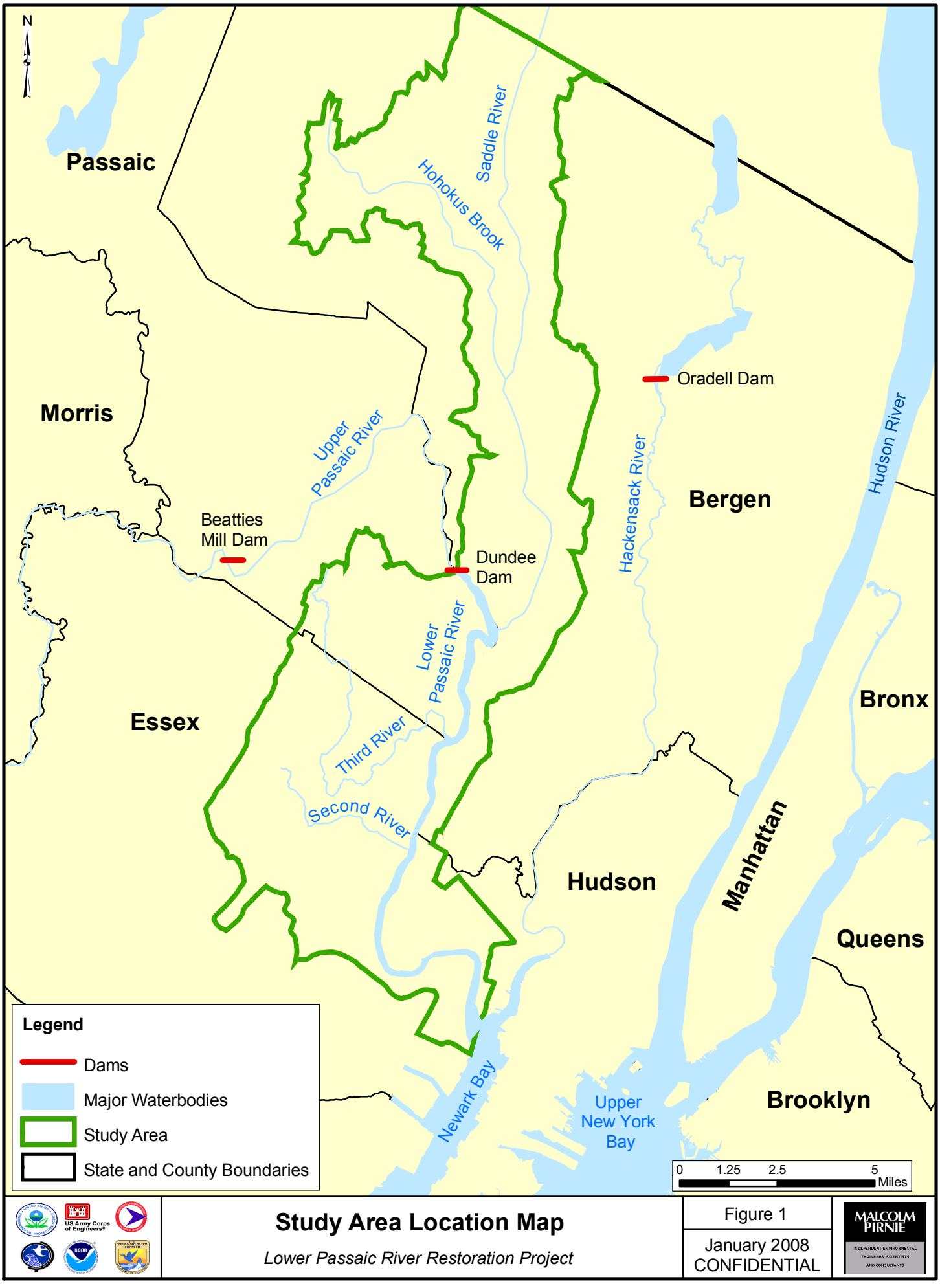

Study Area Location Map

Lower Passaic River Restoration Project

Figure 1

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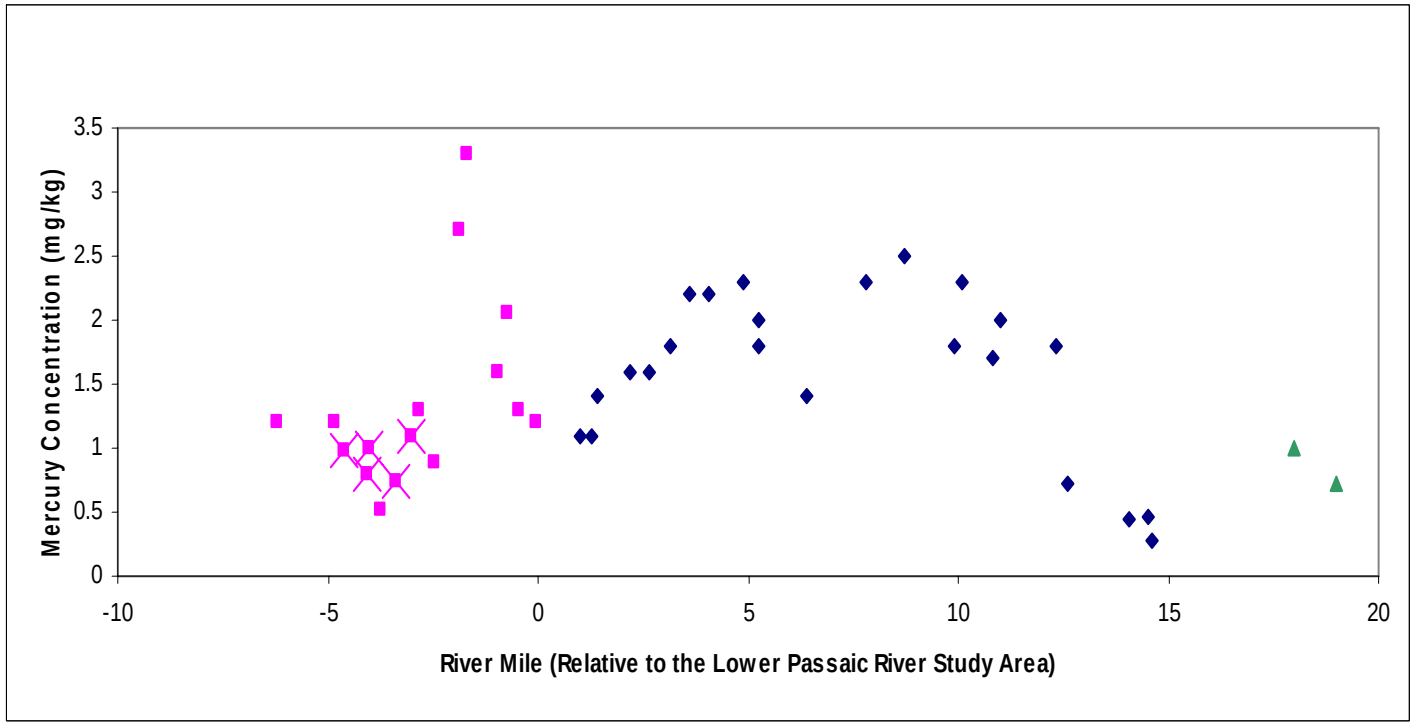

Legend

- Lower Passaic River Mercury
- Newark Bay Mercury
- Newark Bay End Member
- Dundee Lake

Notes

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Data Source:

Newark Bay Phase 2 RIWP (October 2006). Samples collected in October to December 2005.

Dundee Lake Core Tops USEPA 2007 High Resolution Sediment Core Program for Above Dundee Dam, collected by Malcolm Pirnie, Inc. for USEPA.

Passaic Hg data are UNVALIDATED Surface Sediment data collected in 2007 by Malcolm Pirnie, Inc. for USEPA.

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Mercury Concentrations vs River Mile

Lower Passaic River Restoration Project

Figure 2

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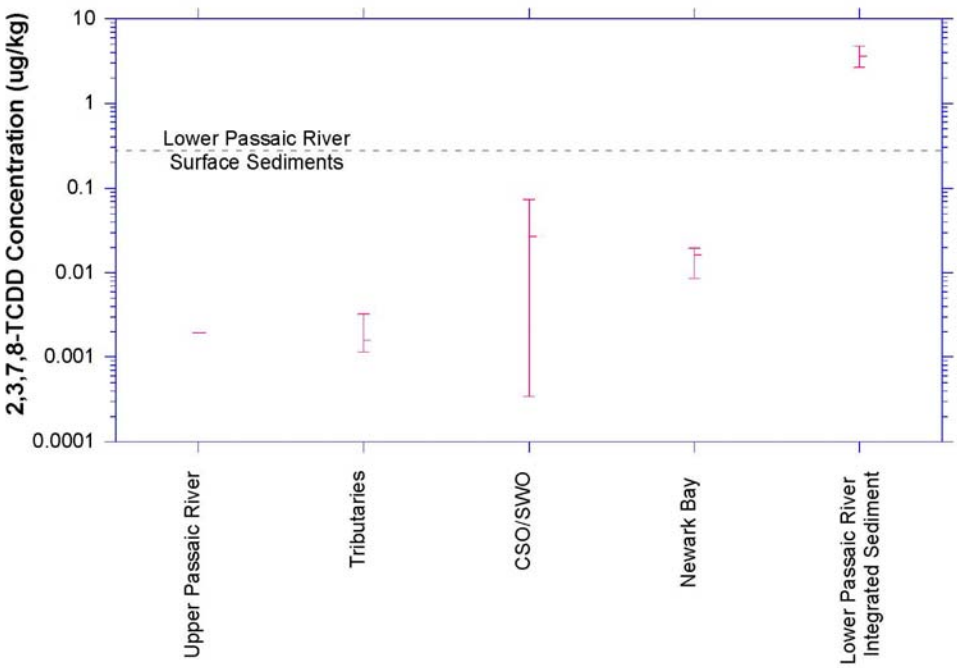
Solids Contribution for 2,3,7,8-TCDD



Legend

- Maximum
- Mean
- Minimum

Notes

See below.

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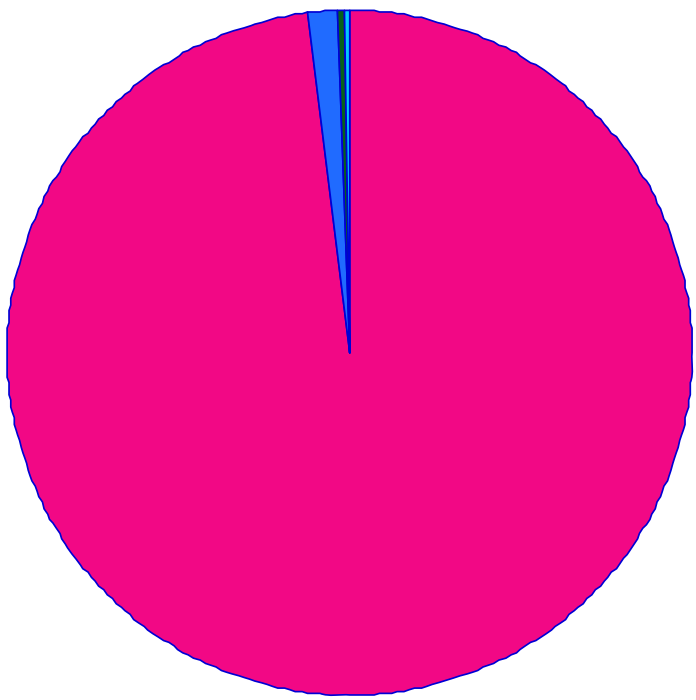
2,3,7,8-TCDD Mass Balance



Legend

- Lower Passaic River Integrated Sediment
- Newark Bay
- Upper Passaic River
- Tributaries
- CSO/SWO

Notes

"Upper Passaic River" is the core top from Dundee Lake at RM18.3.

"Tributaries" is a watershed-weighted average of Saddle River, Second River, and Third River.

"Newark Bay" represents the average of the five southern samples only.

"Lower Passaic River Integrated Sediment" is the average of high resolution cores.

Averages were calculated using all available data.

Reprint from Appendix D of FFS

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Solids Contribution and Mass Balance for 2,3,7,8-TCDD

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Figure 3

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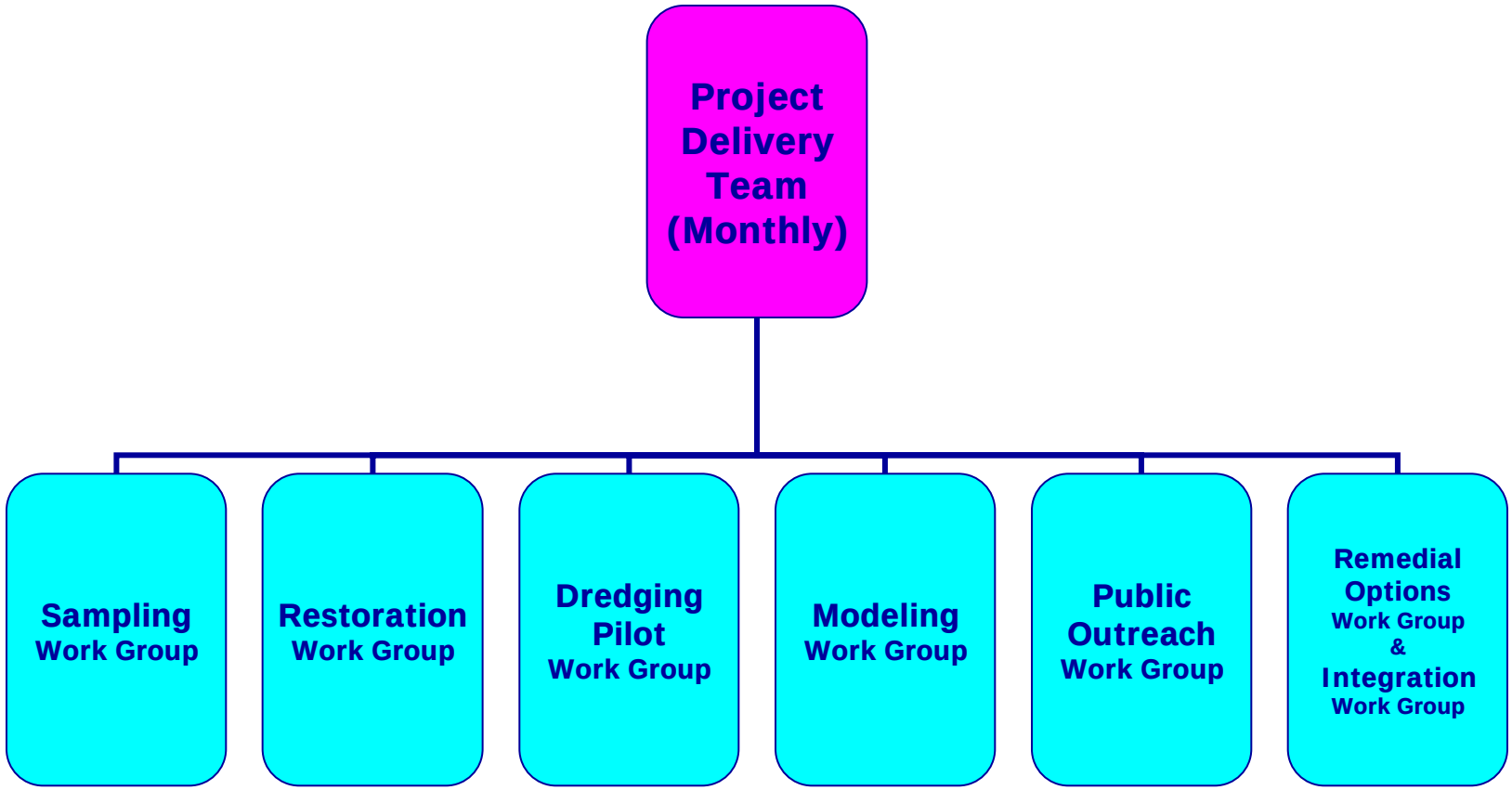

Notes

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Project Delivery Team

Lower Passaic River Restoration Project

Figure 4

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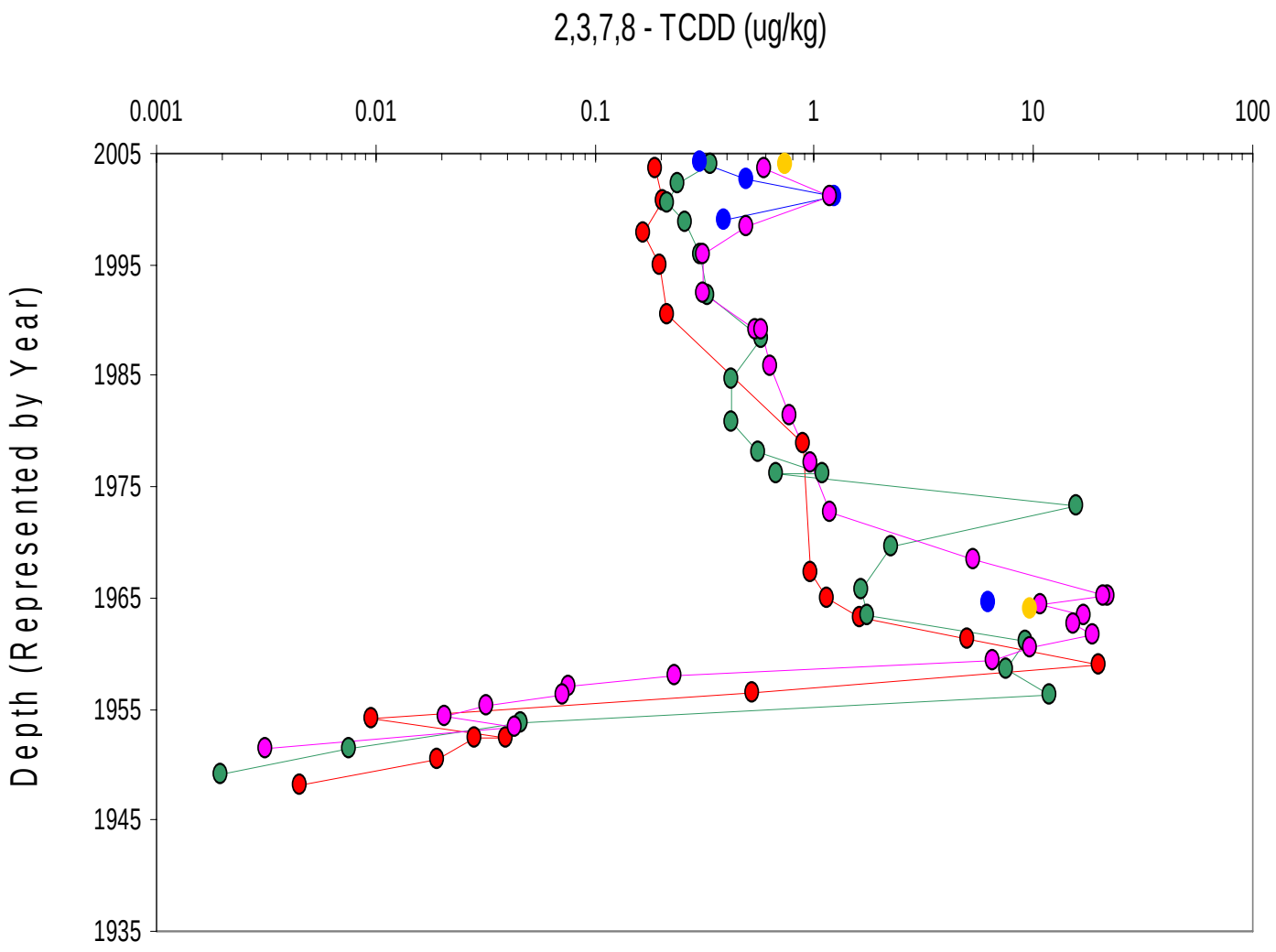

Legend

- RM 1.4 Sediment Core
- RM 2.2 Sediment Core
- RM 7.8 Sediment Core
- RM 11 Sediment Core
- RM 12.6 Sediment Core

Notes

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Data Source:
2005 USEPA High Resolution Sediment Coring Program

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2,3,7,8 – TCDD vs Depth (years)

Lower Passaic River Restoration Project

Figure 5

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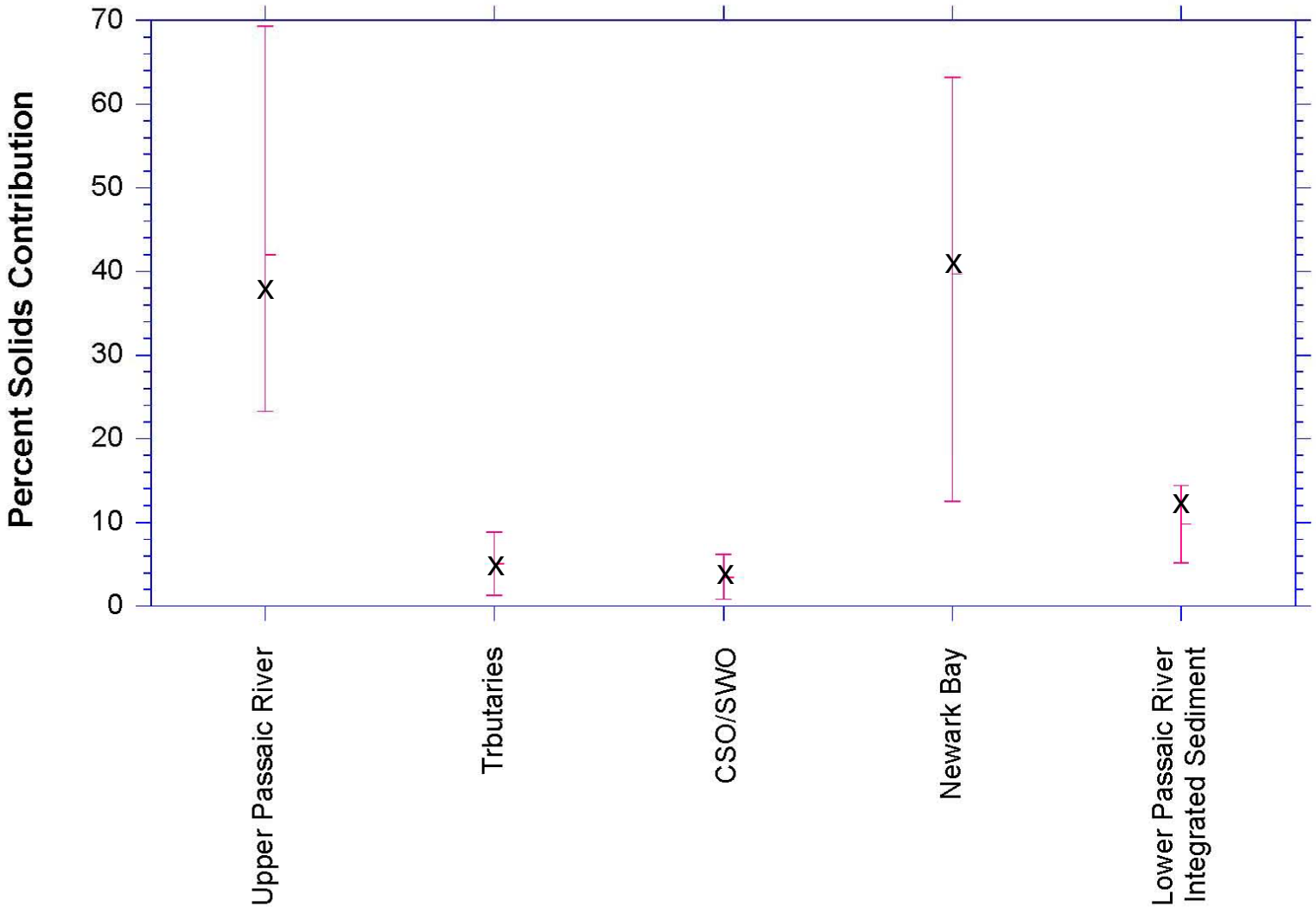

Legend

- Maximum
- Mean
- Minimum

x Result from Deterministic Approach

Notes

"Upper Passaic River" is the core top from Dundee Lake at RM18.3.

"Tributaries" is a watershed-weighted average of Saddle River, Second River, and Third River.

"Newark Bay" represents the average of the five southern samples only.

"Lower Passaic River Integrated Sediment" is the length-weighted average concentration of high resolution cores.

Solids Contribution to the Lower Passaic River Based on Monte Carlo Simulations

Lower Passaic River Restoration Project

Figure 6

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Legend

- Dredging followed by Backfill
- Capping with Pre-Dredging
- Navigation Channel
- Shoreline as defined by the New Jersey Department of Environmental Protection
- Area of Focus/Proposed Extent of Cap or Backfill
- Bridges and Bridge Abutments
- Tidal Mudflats
- Political Boundary - Municipalities
- Political Boundary - Counties

Kearny

East Newark

Harrison

Newark

Jersey City

Depth of Navigational Channel: 30 feet

0 1,000 2,000 4,000 Feet

Notes on Data Sources
Bridge and Bridge Abutments - NOAA electronic navigation data
Federal Navigation Channel - USACE
Lower Passaic River Centerline - Generated by Malcolm Pirnie, Inc. based on Federal Channel.

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Dredging Alternatives

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N

Legend

- Capping with Pre-Dredging
- Armored Areas
- Navigation Channel
- Shoreline as defined by the New Jersey Department of Environmental Protection
- Area of Focus/Proposed Extent of Cap or Backfill
- Bridges and Bridge Abutments
- Tidal Mudflats
- Political Boundary - Municipalities
- Political Boundary - Counties

Kearny

East Newark

Harrison

Newark

Jersey City

8 7 6 5 4 3 2 1 0

Limited Hotspot Removal
(at 80 Lister Avenue Vicinity)

Depth of Navigational
Channel: 30 feet

0 1,000 2,000 4,000 Feet

Notes on Data Sources
Bridge and Bridge Abutments - NOAA electronic navigation data
Federal Navigation Channel - USACE
Lower Passaic River Centerline - Generated by Malcolm Pirnie, Inc. based on Federal Channel.

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Capping Alternatives

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Figure 8

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TABLES

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Table 1: List of Historical Facts and Observations

Observations	
History	
H-1	A federally authorized navigation channel was constructed in the early twentieth century, extending from RM0 to RM15. The channel was largely neglected post-1950 and rapidly filled in over the latter half of the twentieth century. A comparison of the original authorized channel depths and the current channel depths indicates that 20 feet or more of sediment has refilled the channel in some locations.
H-2	Historical contaminant discharges to the Lower Passaic River began in the late nineteenth century, with growth of the American Industrial Revolution and the construction and operation of coal gasification plants along the banks of the river.
H-3	Oily, Polyaromatic Hydrocarbon-bearing layers can be found below radiodated sediments. Mercury and other metals can also be found in this layer, which is typically sand, as compared to the silt layers which have been radiodated.
H-4	Production of the herbicide Agent Orange (and likely associated discharges to the Lower Passaic River) began in the 1950s, coincidental with the lack of maintenance of the navigational channel. Production of Agent Orange ended in the 1970s. (Bopp *et al.* , 1991)
Passaic River	
PR-1	The Lower Passaic River is a partially stratified tidal estuary. With an average tidal maximum of roughly 7 feet above mean low water and a mean channel depth of about 15 feet, tidal exchange serves to move the salt front several miles with each tidal cycle, accompanied by current speeds greater than 2 meters per second. Its freshwater flows are fairly "flashy", often followed by periods of low flow, resulting in a frequent migration of the salt front from the mouth of the river to its uppermost reaches.
PR-2	Above RM8, the current channel depths are similar to the authorized depths, suggesting relatively little sediment accumulation in the channel above this point, perhaps 2 feet or less.
PR-3	Sediment texture changes from predominantly fine-grained sediments to coarser sediments moving from the mouth to the head-of-tide. Much of this change occurs at RM8 where the river becomes distinctly narrower upstream. This change was documented by a side-scan sonar survey and correlates with the change in channel cross sectional area.
PR-4	Annual sediment accumulation in the lower 8 miles of the Lower Passaic River is the equivalent of approximately one to one-and-one-quarter inches per year. This represents an annual sediment volume of 40,000 to 50,000 cubic yards each year. This observation is based on an extensive set of bathymetric surveys, extending from 1989 to 2004. A recently completed 2007 survey is undergoing review.
PR-5	Delivery of solids at the head-of-tide is approximately 50,000 cubic yards per year, based on USGS records of flow and suspended solids at Little Falls (approximately 10 miles upstream) and United States Geological Survey (USGS) records for the Saddle River at Lodi, New Jersey.

Table 1: List of Historical Facts and Observations

PR-6	Despite the large net average annual rate of deposition, local rates of sediment accumulation vary widely, with many areas experiencing episodes of deposition and erosion. Some areas can be identified as routinely depositional or routinely erosional but most areas experience a range of conditions over time (depositional, erosional, and no net change). Rates of erosion and deposition greater than 12 inches per year are often observed in a limited number of areas. This observation is based on a series of closely matched bathymetric surveys conducted from 1995 to 2001, covering RM0.9 to RM7. These rates have been assumed to apply to RM0 to RM8 for the purposes of estimates of annual deposition.
PR-7	Interannual rates of deposition for the lower 8 miles can also vary widely, with integrated river-wide rates of deposition and erosion as much as 2 to 3 greater than the long-term net average.
PR-8	The interannual variation in river bottom elevation indicates that the gross movement of sediments each year is much larger than the net annual accumulation.
PR-9	The surface concentrations of 2,3,7,8-TCDD exhibit little trend with river mile, based on the 1995 survey covering RM0.9 to RM7 and the 2005 dated sediment core survey. (An additional Be^7-bearing core top survey was completed in December 2007 and is undergoing analysis and review.)
PR-10	The concentrations of 2,3,7,8-TCDD in the solids found in external discharges and water bodies to the Lower Passaic River are at least one order of magnitude lower than the concentrations observed in the surface sediments of the Lower Passaic River. This includes the tributaries to the Lower Passaic River, the storm water outfalls, the combined sewer overflows, and Newark Bay. The data for CSO concentrations was derived from CARP measurements of 4 Hackensack River CSOs and one Passaic River CSO. (USEPA is currently pursuing measurements of additional Lower Passaic River CSOs as well as additional stormwater outfall and tributary measurements).
PR-11	Recently deposited sediments of the Lower Passaic River (Be^7-bearing sediments obtained in December 2007) exhibit essentially one mercury-to-aluminum, one cadmium-to-aluminum, one chromium-to aluminum, one copper-to aluminum, and one lead-to-aluminum ratio throughout the lower 12 miles of the Lower Passaic River.
PR-12	Concentrations of mercury, cadmium, chromium, copper, and lead show no trend with river mile from RM3 to RM12. Concentrations above RM12 and below RM3 decline relative to the concentration plateau observed in RM3 to RM12.
PR-13	Dated sediment cores obtained from RM1.4 to RM12.6 show close agreement in the contaminant concentrations among sediments of similar age over the last 25 years. The histories recorded by these cores over this period show only gradual changes from year to year.
PR-14	These dated sediment cores also show concentration maximums of similar magnitude at depth in the cores. (*i.e.,* The peak concentrations are nearly all the same.)
PR-15	For PAHs, mean concentrations on Upper Passaic River solids are about twice that of the concentrations on Lower Passaic River surface sediments.

PR-16	For high molecular weight (HMW) PCBs, mean concentrations on Upper Passaic River solids are equal to that of the concentrations on Lower Passaic River surface sediments. For low molecular weight (LMW) PCBs, Upper Passaic River sediments are roughly 2 times lower in concentration than Lower Passaic River sediments.
PR-17	The polychlorodibenzodioxin (PCDD) contamination of the Lower Passaic River can be identified by its uniquely high proportion of 2,3,7,8-TCDD in the total tetrachlorodioxin homologue fraction. Typically, the ratio is approximately 0.7 (2,3,7,8-TCDD/Total TCDD) in recently deposited Lower Passaic River sediments. The ratio can be as high as 0.9 or 1.0 in historical sediments from the Lower Passaic. By comparison, ratios observed in atmospheric fallout, sewage effluent, the Upper Passaic River, and the external tributaries to the Lower Passaic center around **0.05**, or more than an order of magnitude lower than those in the Passaic River.
PR-18	The surface sediments of the Lower Passaic River have a mean 2,3,7,8-TCDD concentration around 300 pg/g. (This is based on a set of 5 dated sediment cores collected in fall 2005 and a series of 104 core tops (0-6 inch) obtained in 1995. An additional survey utilizing Be^7 bearing core tops obtained in December 2007 are currently undergoing analysis.)
PR-19	The inventory of contaminated sediments in the Lower Passaic River is massive, based on either direct measurements by sediment coring or by integration of the originally authorized channel dimensions and the current river bottom surface. Integrating the sediment cores suggests a contaminated sediment inventory of 10 to 12 Million cubic yards (Mcy), with many tons of mercury, PCBs, and DDT, as well as kilograms of 2,3,7,8 TCDD.
PR-20	Concentrations of cadmium, mercury, and copper in Be-7 bearing Upper Passaic River sediments are roughly half that observed in Lower Passaic River sediments. Lead concentrations are lower by only 25 percent relative to the Upper Passaic River while chromium is more than 5 times lower in Upper Passaic River sediments.
Newark Bay	
NB-1	For most contaminants of concern, mean concentrations on Newark Bay solids are substantively lower than those found in the Lower Passaic River. Newark Bay sediment concentrations rapidly decline with distance from the mouth of the Passaic River for all COCs except mercury.
NB-2	The 2,3,7,8-TCDD ratio in Newark Bay sediments is 0.4, substantially lower than that observed in the Lower Passaic River. This means that the tetrachlorodibenzodioxin pool in Newark Bay contains a higher fraction of non-2,3,7,8-TCDD tetrachlorodibenzodioxin.
NB-3	The ratios of cadmium-to-aluminum, chromium-to-aluminum, copper-to aluminum and lead-to-aluminum in Newark Bay are distinctly lower than those of the Lower Passaic River and exhibit a gradient with distance from the mouth of the Lower Passaic River.
NB-4	The ratio of mercury to aluminum is generally lower in Newark Bay than in the Lower Passaic River. However, some samples near the Port Newark Channel exhibit high mercury-to-aluminum ratios.
Dundee Dam	

Table 1: List of Historical Facts and Observations

DD-1	The drainage basin area at Dundee Dam represents about 80 percent of the total upland flow to the Lower Passaic River. The tributaries below this point represent an additional 10 to 15 percent of flow, with SWOs and CSOs representing the remainder. Solids data are available for the Upper Passaic at Little Falls and for the Saddle River at Lodi and suggest comparable solids yields from both watersheds.

Table 2
Average Contaminant Concentrations in Recently Deposited Sediments for the Lower Passaic River and Adjoining Water Bodies

Chemical [1,2]	Lower Passaic River Recent Surface Sediment RM 1.4 to 12.6 (Source: EPA 2005) (ug/kg)	Newark Bay Southern Basin Recent Surface Sediments (Source: TSI 2005) (ug/kg)	Upper Passaic River Recent Surface Sediments [3] (Source: EPA 2007) (ug/kg)
Mercury	1,800	930	720
Lead	210,000	77,000	140,000
Cadmium	3,600	640	2,200
Chlordane, gamma (trans)	33	28	43
4,4'-DDE	54	18	26
2,3,7,8-TCDD	0.43	0.02	0.002
Total TCDD	0.59	0.05	0.07
PCB 31	26	12	13
PCB 52	35	7	19
PCB 61+ 70+74+76+66	85	19	38
PCB 83+99	21	4	12
PCB 90+101+113	34	8	22
PCB 93+95+98+100+102	28	6	19
PCB 110+115+111	35	9	25
PCB 129+138+158+160+163+164	45	7	41
PCB 139+140+147+149	34	6	27
PCB 170	11	1.5	10
PCB 180+193	27	4.2	24
Benz(a)anthracene	3,100	350	5,800
Benzo(a)pyrene	3,600	400	7,100
Chrysene	4,300	370	8,300
Fluoranthene	6,500	510	10,000
Indeno(1,2,3-cd)pyrene	2,900	310	4,500
Pyrene	6,100	580	11,000

Notes:
1. Shaded areas represent the highest concentration among the three areas.
2. Mulitple PCB compounds are grouped based on their chromatographic coelution.
3. Results are for a single sample.

Table 5: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Exposure Assessment	EPCs for biota	95 percent UCLs on the mean were calculated from measured data collected from numerous samples distributed across the exposure area and used as the EPC to calculate risk. The difference between the 95 percent UCL and mean indicates the level of uncertainty associated with EPC estimation.	Risks for some compounds with low frequency of detection may be overestimated by using ½ the detection limit for non-detected values.
	Fish and crab tissue data used to derive EPC	Historical data used to calculate the EPC for fish may have at times included samples consisting of the whole body rather than only fillets. Historical data used to calculate the EPC for crab incorporated the hepatopancreas results.	Incorporating all portions of the fish may result in overestimating the concentrations if in fact individuals tend to mainly eat fillets or muscle tissue. Risks for ingestion of crab may be overestimated because data from the hepatopancreas-specific samples were included in the EPC.
	Use of the white perch and American eel to derive the EPC for fish ingestion	Use of a weighted average fish concentration, consisting of white perch and American eel, was used to represent a broad range of fish species that could be caught and consumed. However, the assumption is that fish species are equally caught and consumed.	Risks may be overestimated or underestimated for individuals who consume only a specific species. For example, risks for individuals who consume only white perch would be underestimated because concentrations in white perch were always higher than the American eel. A weighted average of the two fish species lowered the EPC. On the other hand, the risk for those individuals consuming only American eel would be overestimated.
	Receptors and exposure parameters	Selecting the most representative exposure parameters for the angling activities/habits is difficult, especially for exposure duration, exposure frequency, and fish ingestion rates.	Risks may be overestimated or underestimated for this site.
	Receptors and exposure parameters	Ingestion rate for consumption of crab was based on a 3-month period during which individuals reported they caught crab.	This rate did not take into consideration the number of meals eaten throughout the year when individuals continued to catch crab beyond the 3-month period or ate crab that had been caught during the 3- month period and frozen. Therefore, risks may be underestimated.
		Other potentially complete exposure pathways for the anglers were not included (*e.g.*, dermal contact with sediment). In addition, exposure to dioxin and dioxin-like compounds in sensitive subpopulations such as breast-fed children was not evaluated.	Exclusion of these additional pathways would underestimate the risks for the site.

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Table 5: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Toxicity Assessment	Toxicity data (general)	Toxicity values for dioxin, PCBs, and mercury are based on an assessment of animal and human data. In some cases, animal data were used as the basis for the toxicity values that were further extrapolated to humans.	Because the most conservative values available are typically used, risks are more likely to be overestimated than underestimated.
	1998 vs. 2005 TEF values	The WHO released its re-evaluation of human and mammalian TEFs for dioxins and dioxin-like compounds performed in 2005.	Risks using the 2005 TEF values were virtually equal to those based on the 1998 values.
	Dioxin reassessment	USEPA is conducting a scientific reassessment of the health risks of exposure to dioxin and dioxin-like compounds in light of significant advances in scientific understanding of mechanisms of dioxin toxicity, significant new studies of dioxin's carcinogenic potential in humans, and increased evidence of other adverse health effects.	Future modifications for determining cancer and noncancer effects may lead to an overestimation or underestimation of risks and noncancer health hazards.
Hazard Identification	Identification of COPCs for quantitative evaluation	Only a subset of contaminants that capture the primary risk drivers were carried through the risk assessment process.	Risks are underestimated.
		COPCs associated with other environmental media (*e.g.*, sediment and surface water) were not evaluated.	Risks are underestimated.
	Mercury and methyl mercury	Due to lack of methyl mercury data in the biota tissue data, results for mercury were used as surrogate for methyl mercury based on fate and transport properties of mercury in the environment and the toxicokinetics of mercury in the biota. This assumes that all mercury contained in fish and crab eaten by humans is present as methyl mercury.	Risks are likely overestimated.

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Table 5: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Risk Characterization	Distinguishing site-related risks from background and/or ambient risks	Contributions from background conditions were not assessed in the risk assessment based on the lack of information.	The calculated risks may be overestimated, but the extent of this overestimation cannot be determined.
	Consumption of both fish and crab	Risks were derived assuming that the receptors ate fish or crab, but not both.	Risks may be underestimated for individuals who eat both fish and crab. However, for individuals eating both crab and fish, the ingestion rates for both these would be expected to decrease; therefore, risks would be overestimated if the same ingestion rates were assumed.
	Thresholds that have been used for establishing consumption advisories	The information presented regarding the concentration of mercury in fish used to establish fish advisories for the general and vulnerable portions of the human population (*e.g.*, children and pregnant women) also identify potential concerns for the ingestion of mercury contaminated fish at varying concentrations.	Noncancer risks may be underestimated for vulnerable portions of the population.

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Table 6: Summary of Major Uncertainties in the Ecological Risk Assessment and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Problem Formulation	Identification of COPECs for quantitative evaluation	Only a subset of contaminants likely comprising the primary risk drivers at the site were selected and evaluated.	Risks are somewhat underestimated; however, exposures to the selected COPECs likely represent a substantial majority of the total hazards posed to ecological receptors.
		COPECs associated with other environmental media (*e.g.*, surface water) were not considered.	Risks are underestimated.
	Mercury and methyl mercury	Due to lack of methyl mercury data in the biota tissue data, results for mercury were used as surrogate methyl mercury. This assumes that all mercury bioaccumulated in the food chain is present as methyl mercury.	Although the hazards may be overestimated, the overall uncertainty is considered low because methyl mercury generally constitutes a substantial majority of the mercury bioaccumulated in fish tissue.
	Evaluated exposure pathways	Other potentially complete exposure pathways for fish and wildlife and fish were not included (*e.g.*, dermal contact with sediment; consumption of contaminated drinking water). In addition, exposure to dioxin and dioxin-like compounds in sensitive critical life stages (*e.g.*, fish embryos) was not explicitly evaluated.	Exclusion of these additional pathways would underestimate the risks for the site.
	Receptors and life stage evaluated	Wildlife species with foraging habits other than piscivorous were not evaluated.	It is anticipated that wildlife consumption of aquatic prey, including fish and shellfish, would result in the highest dietary exposures to COPECs; it is likely that risk to other wildlife species are of lower magnitude than reported in this assessment.
Risk Characterization	Distinguishing site-related risks from background and/or ambient risks	A portion of the estimated hazards may be attributed to the presence of naturally occurring constituents or constituents that are present at the site because of regional anthropogenic sources (*e.g.*, mercury).	The effect of including background and ambient constituents in the risk assessment is that the calculated risks overestimate the site-related risks that are due to chemical releases.
Exposure Assessment	EPCs for biota tissue	95 percent UCLs were calculated from measured data collected from numerous samples distributed across the exposure area and used as the EPC to calculate risk.	Risks for some compounds with low frequency of detection may be overestimated or underestimated because it was assumed that samples reported as "ND" contained a concentration equal to one-half the detection limit.

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Table 6: Summary of Major Uncertainties in the Ecological Risk Assessment and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Exposure Assessment	Use of a AE/WP fish composite	Use of EPCs based on a combination of AE/WP tissue data to represent exposures to piscivorous wildlife assumes that they are from the Lower Passaic River and that each of these species is equally consumed.	Risk estimates for individual mink that consume only white perch would be underestimated because concentrations in white perch were always higher than the American eel. Averaging the two fish species would therefore dilute the EPCs. On the other hand, the risk for those individuals consuming only American eel would be overestimated. Exposures would also be overestimated to the extent that wildlife receptors consumed more migratory species such as striped bass, which tend to have lower tissue COPEC concentrations.
	Receptor exposure parameters	Selecting the most representative exposure parameters for the angling activities/habits is difficult, especially for exposure duration, exposure frequency, and fish ingestion rates.	Risk estimates were based on conservative values derived from standard ecological risk guidance (USEPA, 1993a) or professional judgment. It is likely that hazards were overestimated because of the general tendency to select conservative values.
	Use of historical data	Sediment samples dating back to 1994 and biota tissue samples dating back to 1995 were used to develop EPCs in the assessment. These data are up to 12 years old and may not be representative of current conditions.	Inclusion of the historical data may tend to overestimate current exposures and hazards based on trends observed in sediment cores. Calculated multipliers to translate 1995 sediment concentrations to equivalent present-day concentrations range from 0.6 (total PCBs) to 1.0 (DDT); the estimated average multiplier for TCDD is 0.9. The use of historical data would have different impacts on the calculated risks, depending on which COPECs were identified as the primary risk drivers.
	Wildlife diet composition	Literature was referenced to quantify the relative proportion of fish and shellfish in the diets of the modeled wildlife receptors.	Ranges of estimated values generally did not differ dramatically (ranging from 0 to 30 percent in different studies, depending on the particular habitat) and the tissue EPCs are fairly comparable. However, this uncertainty has more significance for the future residual risk analysis because of significant differences in the estimated bioaccumulation factors (BAF) for higher-trophic-level fish and shellfish.

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Table 6: Summary of Major Uncertainties in the Ecological Risk Assessment and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Exposure Assessment	Fish prey trophic level	Wading birds generally take smaller forage fish rather than larger, higher-trophic-status species. Concentrations in mummichog (a forage fish) are approximately an order of magnitude lower than in AE/WP.	Use of the fish EPCs based on a higher-trophic-level dataset likely overestimates risks to wading birds such as the heron. The magnitude of this impact was evaluated by also including an assessment of a diet that consisted of mummichogs.
Toxicity Assessment	Ingestion toxicity data	TRVs are typically based on results of tests performed on test animals and extrapolated to wildlife species; selected values are generally conservatively developed as the lowest LOAEL for well-conducted studies that evaluated ecologically relevant endpoints.	Because the most conservative values available are typically used, risks are more likely to be overestimated than underestimated. In the case of the mink receptor, well-conducted toxicity test results are available and were used to develop the TRVs.
	1998 vs. 2005 TEF values	The WHO released its re-evaluation of human and mammalian TEFs for dioxins and dioxin-like compounds performed in 2005.	An evaluation of the hazards posed based on use of the 2005 TEF values demonstrates that they are comparable to those based on the 1998 values.
	CBR effect thresholds	CBRs were selected based on a review of several large compilations of tissue residue effect data. Study quality is variable and relevance of particular endpoints uneven relative to the assessment endpoints.	Likely risks were overestimated; however, suitable tissue residue data for certain COPECs were limited and may not have included relevant sensitive species or life stages.
		Use of toxicologically unbounded study results to develop CBRs.	In several cases, NOAELs were estimated using an assumed 10-fold extrapolation factor; this may have underestimated or overestimated hazards in the assessment.
		In general, the most sensitive saltwater or estuarine fish species was selected to develop the CBRs. In many cases, CBRs are based on exposure to salmonid species that are known to be sensitive to COPECs such as dioxins, DDT, and mercury.	Species such as salmon and trout are not found in the Lower Passaic River, and hazards identified in the residue-based analysis for the AE/WP are likely overestimated. A separate set of CBRs was also developed for estuarine forage fish such as *Fundulus* spp., and CBRs for these species were, in some cases, higher than for the AE/WP (such as those for TCDD and Total DDT).

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Table 7: Summary of the Human Health PRGs Developed for Fish/Crab Tissue

COPC	PRGs [1] for Fish/Crab Tissue for an Adult Angler			
	Cancer PRGs (ng/g)			Non-cancer PRGs (ng/g)
	$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	
TCDD TEQ	0.000055	0.00055	0.0055	ND [2]
Total PCB	4.1	41	410	56
Chlordane	23	230	2,300	1,407
Methyl mercury	ND [3]			281

ng/g – nanograms per gram of sediment
ND – not determined.
[1] Assumes 40 eight-ounce fish or crab meals per year for 24 years.
[2] No toxicity values are available at this time.
[3] Classification - There is no quantitative estimate of carcinogenic risk from oral exposure.

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Table 8: Summary of the Human Health PRGs Developed for Sediment

COPC	PRGs [1] for Sediment			
	Cancer PRGs (ng/g)			Non-cancer PRGs (ng/g)
	$1x10^{-6}$	$1x10^{-5}$	$1x10^{-4}$	
2,3,7,8-TCDD	0.00027	0.0027	0.027	ND [2]
Total PCB	1.03	10.3	103	14
Chlordane	1.2	12.0	119	72
Mercury	ND [3]			2,814

[1] Assumes 40 eight-ounce fish or crab meals per year for 24 years.
[2] No toxicity values are available at this time.
[3] Classification - There is no quantitative estimate of carcinogenic risk from oral exposure.

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Table 9: Summary of Sediment PRGs for Ecological Receptors

Chemical	Units	Sediment PRGs		Lowest
		Benthos [1]	Wildlife [2]	
Inorganics				
Copper	ng/g	34,000	13,318	Wildlife PRG
Lead	ng/g	46,700	10,606	Wildlife PRG
Mercury	ng/g	150	37	Wildlife PRG
PAHs				
LMW PAH	ng/g	552	-	NOAA ER-L
HMW PAH	ng/g	1700	-	NOAA ER-L
PCB Aroclors				
Total PCBs	ng/g	22.7	365	NOAA ER-L
Pesticides/Herbicides				
DDT	ng/g	1.58	19	NOAA ER-L
Dieldrin	ng/g	0.02	271	NOAA ER-L
Dioxins/Furans				
TCDD TEQ [3]	ng/g	0.0032	0.0025	Wildlife PRG

[1] Benthos PRG derived from ER-L from Long *et al*. (1995), except where noted.

[2] Derived as described in the FFS COPEC Screening Technical Memorandum (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).

[3] Benthic benchmark for 2,3,7,8-TCDD derived by USFWS using sediment chemistry for Newark Bay and oyster effect data presented in Wintermyer and Cooper (2003); wildlife value from USEPA (1993b).

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Table 10: Summary of Fish Tissue PRGs for Ecological Receptors

Chemical	Units	Fish Tissue PRGs		Lowest
		Fish [1]	Wildlife [2]	
Inorganics				
Copper	ng/g	6.3	21,935	Fish
Lead	ng/g	88	700	Fish
Mercury	ng/g	19	40	Fish
PAHs				
LMW PAH	ng/g	89	-	Fish
HMW PAH	ng/g	89	-	Fish
PCB Aroclors				
Total PCBs	ng/g	7.9	676	Fish
Pesticides/Herbicides				
DDT	ng/g	0.3	147	Fish
Dieldrin	ng/g	35	487	Fish
Dioxins/Furans				
TCDD TEQ [3]	ng/g	0.050	0.0007	Wildlife

[1] Based on critical body residuals as summarized in the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).
[2] Derived as described in the FFS COPEC Screening Technical Memorandum (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b); lowest of mammal and avian values.
[3] Low risk fish concentrations for 2,3,7,8-TCDD from USEPA (1993a).

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APPENDICES

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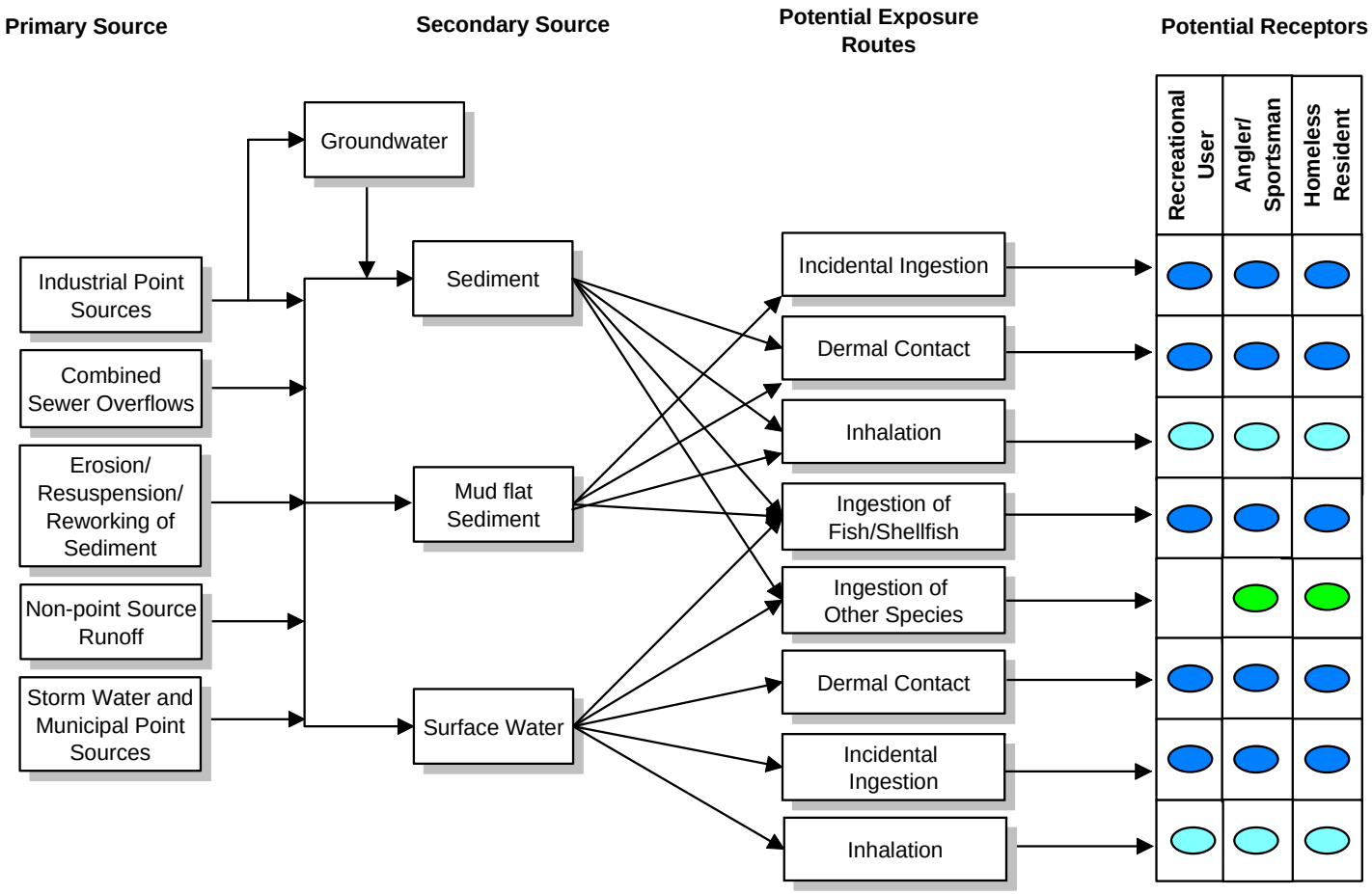
Appendix A

Human Health Risk Assessment



Legend

- Complete, Quantitative Pathway
- Complete, Qualitative Pathway
- Potentially Complete Pathway

Notes

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Human Health Conceptual Site Model

Lower Passaic River Restoration Project

Figure A-1

January 2008

Table 1: Selection of Human Health Exposure Pathways – Passaic River

Scenario Timeframe	Source Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Sediment	Biota Tissue	Fish from 8-mile stretch of Passaic River	Angler/Sportsman	Adult, Adolescent, Child	Ingestion	Quantitative	Many site-related contaminants in sediment have been shown to bioaccumulate in fish. Assumes receptor will consume fish caught from Passaic River and share it with family members.
				Recreational User[(1)]	Adult, Adolescent, Child	Ingestion	Quantitative	
				Homeless Resident	Adult, Adolescent, Child	Ingestion	Quantitative	
			Shellfish from 8-mile stretch of Passaic River	Angler/Sportsman	Adult, Adolescent, Child	Ingestion	Quantitative	Many site-related contaminants in sediment have been shown to bioaccumulate in shellfish. Assumes receptor will consume shellfish caught from Passaic River and share it with family members. Shellfish ultimately evaluated may include clams, mussels, and crabs.
				Recreational User[(1)]	Adult, Adolescent, Child	Ingestion	Quantitative	
				Homeless Resident	Adult, Adolescent, Child	Ingestion	Quantitative	
			Other species (waterfowl, snapping turtle, frog, etc.) from 8-mile stretch of Passaic River	Angler/Sportsman	Adult, Adolescent, Child	Ingestion	Qualitative	The possibility that individuals hunt and consume other species (e.g., waterfowl, frogs, or turtles) will be investigated. Assumes receptors will consume other species caught from Passaic River and share meat with family members. There are limitations associated with a quantitative assessment of this pathway due to the lack of information on tissue concentrations in these species.
				Recreational User[(1)]	Adult, Adolescent, Child	Ingestion	Qualitative	
				Homeless Resident	Adult, Adolescent, Child	Ingestion	Qualitative	

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Table 1: Selection of Human Health Exposure Pathways – Passaic River

Scenario Timeframe	Source Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Sediment	Sediment	Sediments from 8-mile stretch of Passaic River	Angler/Sportsman	Adult, Adolescent	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Angler/Sportsman may contact sediment while fishing or crabbing from the river bank. Inhalation may occur if activities occur in mudflat areas and volatiles are present. Assumes that children accompanying adult angler would be engaging in recreational activities as described for recreational user. **Reserved for evaluation in the Baseline Risk Assessment.**
				Recreational User[(1)]	Adult, Adolescent, Child	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Recreational Users may ingest or otherwise come in contact with contaminated sediment while engaging in activities (swimming, wading, boating, etc.) along the river. Inhalation may also occur if activities occur in mudflat areas. **Reserved for evaluation in the Baseline Risk Assessment.**
				Homeless Resident	Adult, Adolescent, Child	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Resident will refer to transient homeless individuals living in makeshift shelters along the river bank that may contact river sediments during daily activities. **Reserved for evaluation in the Baseline Risk Assessment.**

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Table 1: Selection of Human Health Exposure Pathways – Passaic River

Scenario Timeframe	Source Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Sediment	Water	Surface water from 8-mile stretch of Passaic River	Angler/Sportsman	Adult, Adolescent	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Angler/Sportsman may contact surface water while fishing or crabbing from the river bank. Inhalation may occur if volatiles are present. Assumes that children accompanying adult angler would be engaging in recreational activities as described for recreational user. **Reserved for evaluation in the Baseline Risk Assessment.**
				Recreational User[(1)]	Adult, Adolescent, Child	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Recreational Users will consist of a combined exposure for child, adolescent, and adult who may ingest or otherwise come in contact with contaminated surface water while engaging in activities (swimming, wading, boating) along the river. Inhalation may also occur if activities occur in mudflat areas. Surface water from the river is not used as a domestic water supply. **Reserved for evaluation in the Baseline Risk Assessment.**
				Homeless Resident	Adult, Adolescent, Child	Dermal Contact, Incidental Ingestion, Inhalation	Quantitative	Surface water from the river is not used as a domestic water supply; therefore, resident will refer to homeless individuals living in makeshift shelters along the river bank. **Reserved for evaluation in the Baseline Risk Assessment.**

[(1)] The recreational user encompasses three different types of recreational activities: swimming, wading, and sculling.

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Table 2: Noncarcinogenic Toxicity Data

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfD: Target Organ(s)	
		Value	Units			Source(s)	Date(s)
TCDD TEQ (D/F)	--	--	--	--	--	IRIS	8/23/2006
TCDD TEQ (PCBs)	--	--	--	--	--	IRIS	8/23/2006
Total PCBs [(1)]	Chronic	2.0E-05	mg/kg-day	Immune System, eye	300	IRIS	8/23/2006
4,4'-DDD	--	--	--	--	--	IRIS	8/23/2006
4,4'-DDE	--	--	--	--	--	IRIS	8/23/2006
4,4'-DDT	Chronic	5.0E-04	mg/kg-day	liver	100	IRIS	8/23/2006
Total Chlordane	Chronic	5.0E-04	mg/kg-day	liver	300	IRIS	8/23/2006
Dieldrin	Chronic	5.0E-05	mg/kg-day	liver	100	IRIS	8/23/2006
Methyl mercury	Chronic	1.0E-04	mg/kg-day	central nervous system	10	IRIS	8/23/2006

[(1)] Based on the noncancer toxicity values for Aroclor 1254.

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Table 3: Carcinogenic Toxicity Data

Chemical of Potential Concern	Oral Cancer Slope Factor		Weight of Evidence/ Cancer Guideline Description[(1)]	Oral CSF	
	Value	Units		Source(s)	Date(s)
TCDD TEQ (D/F)	1.50E+05	$(mg/kg\text{-}day)^{-1}$	B2	HEAST	07/31/97
TCDD TEQ (PCBs)	1.50E+05	$(mg/kg\text{-}day)^{-1}$	B2	HEAST	07/31/97
Total PCBs	2.00E+00	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
4,4'-DDD	2.40E-01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
4,4'-DDE	3.40E-01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
4,4'-DDT	3.40E-01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
Total Chlordane	3.50E-01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
Dieldrin	1.60E+01	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	8/23/2006
Methyl mercury	--	--	C	IRIS	8/23/2006

(1) Weight of evidence: B2 - probable human carcinogen; C- possible human carcinogen

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Table 4: Exposure Parameter Values Used for Daily Intake for the Adult – Fish Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_f	Chemical Concentration in Fish	mg/kg wet weight	Site-specific		Site-specific		
	IR_f	Ingestion rate of Fish	g/day	25	USEPA, 1997	8	USEPA, 1997	$Intake = \frac{C_f \times IR_f \times EF \times FI \times (1 - Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Assumed to be one-half RME	
	ED	Exposure Duration (2)	years	24	USEPA, 1989	9	USEPA, 1989	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in fish	Chemical-specific	--	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	70	Mean adult body weight, males and females (USEPA, 1989)	70	Mean adult body weight, makes and females (USEPA, 1989)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	8760	ED (years) x 365 days/year	3285	ED (years) x 365 days/year	

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Table 5: Exposure Parameter Values Used for Daily Intake for the Adult – Crab Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_b	Chemical Concentration in Crab	mg/kg wet weight	Site-specific		Site-specific		
	IR_b	Ingestion rate of Crab	g/day	23	Burger, 2002	16	Burger, 2002	$Intake = \frac{C_b \times IR_b \times EF \times FI \times (1-Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Based on an annualized ingestion rate	
	ED	Exposure Duration	years	24	USEPA, 1989	9	USEPA, 1989	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in crab	0	No data available	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	70	Mean adult body weight, males and females (USEPA, 1989)	70	Mean adult body weight, males and females (USEPA, 1989)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	8760	ED (years) x 365 days/year	3285	ED (years) x 365 days/year	

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Table 6: Exposure Parameter Values Used for Daily Intake for the Adolescent – Fish Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_f	Chemical Concentration in Fish	mg/kg wet weight	Site-specific		Site-specific		
	IR_f	Ingestion rate of Fish	g/day	17	2/3 the adult ingestion rate (USEPA, 1997)	5	2/3 the adult ingestion rate (USEPA, 1997)	$Intake = \frac{C_f \times IR_f \times EF \times FI \times (1 - Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Based on an annualized ingestion rate	
	ED	Exposure Duration	years	9	Assumed	6	EPA default (USEPA, 1991)	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in fish	Chemical-specific	--	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	54.5	Mean weight, males and females age 10-17 (USEPA, 2002c)	54.5	Mean weight, males and females age 10-17 (USEPA, 2002c)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	3285	ED (years) x 365 days/year	1825	ED (years) x 365 days/year	

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Table 7: Exposure Parameter Values Used for Daily Intake for the Adolescent – Crab Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_b	Chemical Concentration in Crab	mg/kg wet weight	Site-specific		Site-specific		
	IR_b	Ingestion rate of Crab	g/day	15	2/3 the adult ingestion rate (USEPA, 1997)	11	2/3 the adult ingestion rate (USEPA, 1997)	$Intake = \frac{C_b \times IR_b \times EF \times FI \times (1-Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Based on an annualized ingestion rate	
	ED	Exposure Duration	years	9	Assumed (from age 10 through 18)	6	Standard EPA default (USEPA, 1991)	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in fish	Chemical-specific	--	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	54.5	Mean weight, males and females age 10-17 (USEPA, 2002c)	54.5	Mean weight, males and females age 10-17 (USEPA, 2002c)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	3285	ED (years) x 365 days/year	1825	ED (years) x 365 days/year	

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Table 8: Exposure Parameter Values Used for Daily Intake for the Child – Fish Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_f	Chemical Concentration in Fish	mg/kg wet weight	Site-specific		Site-specific		
	IR_f	Ingestion rate of Fish	g/day	8	1/3 of the adult ingestion rate (USEPA, 1997)	3	1/3 of the adult ingestion rate (USEPA, 1997)	$Intake = \frac{C_f \times IR_f \times EF \times FI \times (1-Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Based on an annualized ingestion rate	
	ED	Exposure Duration	years	6	EPA default (USEPA, 1991)	3	Assumed	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in fish	Chemical-specific	--	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	15	Mean child weight (USEPA, 1989)	15	Mean child weight (USEPA, 1989)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	2190	ED (years) x 365 days/year	1095	ED (years) x 365 days/year	

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Table 9: Exposure Parameter Values Used for Daily Intake for the Child – Crab Ingestion

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/Reference	CT Value	CT Rationale/Reference	Intake Equation/Model Name
Ingestion	C_b	Chemical Concentration in Crab	mg/kg wet weight	Site-specific		Site-specific		
	IR_b	Ingestion rate of Crab	g/day	8	1/3 of the adult ingestion rate (USEPA, 1997)	5	1/3 of the adult ingestion rate (USEPA, 1997)	$Intake = \frac{C_b \times IR_b \times EF \times FI \times (1-Loss) \times ED \times CF}{BW \times AT}$
	FI	Fraction from Source	unitless	1	Assumes 100% exposure is from Passaic River	1	Assumes 100% exposure is from Passaic River	
	EF	Exposure Frequency	days/year	365	USEPA, 1989	365	Based on an annualized ingestion rate	
	ED	Exposure Duration	years	6	Standard EPA default (USEPA, 1991)	3	Assumed	
	Loss	Cooking Loss	g/g	0	Assumes 100% chemical remains in crab	0	No data available	
	CF	Conversion Factor	kg/g	1.00E-03	--	1.00E-03	--	
	BW	Body Weight	kg	15	Standard EPA default (USEPA, 1991)	15	Standard EPA default (USEPA, 1991)	
	AT-C	Averaging Time (Cancer)	days	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	25550	70-year lifetime exposure x 365 days/year (USEPA, 1989)	
	AT-NC	Averaging Time (Noncancer)	days	2190	ED (years) x 365 days/year	1095	ED (years) x 365 days/year	

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Table 10: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Exposure Assessment	EPCs for biota	95% UCLs on the mean were calculated from measured data collected from numerous samples distributed across the exposure area and used as the EPC to calculate risk. The difference between the 95% UCL and mean indicates the level of uncertainty associated with EPC estimation.	Risks for some compounds with low frequency of detection may be overestimated by using ½ the detection limit for non-detected values.
	Fish and crab tissue data used to derive EPC	Historical data used to calculate the EPC for fish may have at times included samples consisting of the whole body rather than only fillets. Historical data used to calculate the EPC for crab incorporated the hepatopancreas results.	Incorporating all portions of the fish may result in overestimating the concentrations if in fact individuals tend to mainly eat fillets or muscle tissue. Risks for ingestion of crab may be overestimated because data from the hepatopancreas-specific samples were included in the EPC.
	Use of a the white perch and American eel to derive the EPC for fish ingestion	Use of a weighted average fish concentration, consisting of white perch and American eel, was used to represent a broad range of fish species that could be caught and consumed. However, the assumption is that fish species are equally caught and consumed.	Risks may be overestimated or underestimated for individuals who consume only a specific species. For example, risks for individuals who consume only white perch would be underestimated because concentrations in white perch were always higher than the American eel. A weighted average of the two fish species lowered the EPC. On the other hand, the risk for those individuals consuming only American eel would be overestimated.
	Receptors and exposure parameters	Selecting the most representative exposure parameters for the angling activities/habits is difficult, especially for exposure duration, exposure frequency, and fish ingestion rates.	Risks may be overestimated or underestimated for this site.
	Receptors and exposure parameters	Ingestion rate for consumption of crab was based on a 3-month period during which individuals reported they caught crab.	This rate did not take into consideration the number of meals eaten throughout the year when individuals continued to catch crab beyond the 3-month period or ate crab that had been caught during the 3- month period and frozen. Therefore, risks may be underestimated.
		Other potentially complete exposure pathways for the anglers were not included (*e.g.*, dermal contact with sediment). In addition, exposure to dioxin and dioxin-like compounds in sensitive subpopulations such as breast-fed children was not evaluated.	Exclusion of these additional pathways would underestimate the risks for the site.

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Table 10: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Toxicity Assessment	Toxicity data (general)	Toxicity values for dioxin, PCBs, and mercury are based on an assessment of animal and human data. In some cases, animal data were used as the basis for the toxicity values that were further extrapolated to humans.	Because the most conservative values available are typically used, risks are more likely to be overestimated than underestimated.
	1998 vs. 2005 TEF values	The WHO released its re-evaluation of human and mammalian TEFs for dioxins and dioxin-like compounds performed in 2005.	Risks using the 2005 TEF values were virtually equal to those based on the 1998 values.
	Dioxin reassessment	USEPA is conducting a scientific reassessment of the health risks of exposure to dioxin and dioxin-like compounds in light of significant advances in scientific understanding of mechanisms of dioxin toxicity, significant new studies of dioxin's carcinogenic potential in humans, and increased evidence of other adverse health effects.	Future modifications for determining cancer and noncancer effects may lead to an overestimation or underestimation of risks and noncancer health hazards.
Hazard Identification	Identification of COPCs for quantitative evaluation	Only a subset of contaminants that capture the primary risk drivers were carried through the risk assessment process.	Risks are underestimated.
		COPCs associated with other environmental media (*e.g.*, sediment and surface water) were not evaluated.	Risks are underestimated.
	Mercury and methyl mercury	Due to lack of methyl mercury data in the biota tissue data, results for mercury were used as surrogate for methyl mercury based on fate and transport properties of mercury in the environment and the toxicokinetics of mercury in the biota. This assumes that all mercury contained in fish and crab eaten by humans is present as methyl mercury.	Risks are likely overestimated.

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Table 10: Summary of Major Uncertainties in the HHRA and Estimated Impacts on Calculated Risks

Risk Assessment Step	Source of Parameter Uncertainty	Description of Uncertainty	Impact on Calculated Risks
Risk Characterization	Distinguishing site-related risks from background and/or ambient risks	Contributions from background conditions were not assessed in the risk assessment based on the lack of information.	The calculated risks may be overestimated, but the extent of this overestimation cannot be determined.
	Consumption of both fish and crab	Risks were derived assuming that the receptors ate fish or crab, but not both.	Risks may be underestimated for individuals who eat both fish and crab. However, for individuals eating both crab and fish, the ingestion rates for both these would be expected to decrease; therefore, risks would be overestimated if the same ingestion rates were assumed.
	Thresholds that have been used for establishing consumption advisories	The information presented regarding the concentration of mercury in fish used to establish fish advisories for the general and vulnerable portions of the human population (*e.g.*, children and pregnant women) also identify potential concerns for the ingestion of mercury contaminated fish at varying concentrations.	Noncancer risks may be underestimated for vulnerable portions of the population.

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Table 11: Summary of RME Risk/Hazard for an Adult

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	5.E-03	ND
TCDD TEQ (PCBs)	1.E-03	ND
Total PCBs	8.E-04	61
4,4'-DDD	4.E-06	ND
4,4'-DDE	1.E-05	ND
4,4'-DDT	3.E-06	0.05
Total Chlordane	8.E-05	1
Dieldrin	5.E-05	0.2
Methyl mercury	ND	1
Exposure Route Total	7.E-03	64
Exposure Point Total	7.E-03	64
Exposure Medium Total	7.E-03	64
Crab Ingestion		
TCDD TEQ (D/F)	3.E-03	ND
TCDD TEQ (PCBs)	7.E-03	ND
Total PCBs	1.E-03	85
4,4'-DDD	4.E-06	ND
4,4'-DDE	1.E-05	ND
4,4'-DDT	9.E-06	0.2
Total Chlordane	1.E-06	0.02
Dieldrin	3.E-05	0.1
Methyl mercury	ND	0.3
Exposure Route Total	1.E-02	86
Exposure Point Total	1.E-02	86
Exposure Medium Total	1.E-02	86

ND - not determined because toxicity values are not available for this exposure route.
mg/kg - milligram per kilogram

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Table 12: Summary of RME Risk/Hazard for an Adolescent

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	1.E-03	ND
TCDD TEQ (PCBs)	5.E-04	ND
Total PCBs	3.E-04	52
4,4'-DDD	1.E-06	ND
4,4'-DDE	4.E-06	ND
4,4'-DDT	1.E-06	0.05
Total Chlordane	2.E-05	1
Dieldrin	2.E-05	0.2
Methyl mercury	ND	1
Exposure Route Total	2.E-03	55
Exposure Point Total	2.E-03	55
Exposure Medium Total	2.E-03	55
Crab Ingestion		
TCDD TEQ (D/F)	1.E-03	ND
TCDD TEQ (PCBs)	2.E-03	ND
Total PCBs	4.E-04	72
4,4'-DDD	1.E-06	ND
4,4'-DDE	4.E-06	ND
4,4'-DDT	3.E-06	0.1
Total Chlordane	5.E-07	0.02
Dieldrin	1.E-05	0.1
Methyl mercury	ND	0.3
Exposure Route Total	4.E-03	72
Exposure Point Total	4.E-03	72
Exposure Medium Total	4.E-03	72

ND - not determined because a toxicity value is not available for this exposure route.
mg/kg - milligram per kilogram

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Table 13: Summary of RME Risk/Hazard for a Child

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	2.E-03	ND
TCDD TEQ (PCBs)	6.E-04	ND
Total PCBs	3.E-04	95
4,4'-DDD	2.E-06	ND
4,4'-DDE	5.E-06	ND
4,4'-DDT	1.E-06	0.1
Total Chlordane	3.E-05	2
Dieldrin	2.E-05	0.3
Methyl mercury	ND	2
Exposure Route Total	3.E-03	99
Exposure Point Total	3.E-03	99
Exposure Medium Total	3.E-03	99
Crab Ingestion		
TCDD TEQ (D/F)	1.E-03	ND
TCDD TEQ (PCBs)	3.E-03	ND
Total PCBs	5.E-04	139
4,4'-DDD	2.E-06	ND
4,4'-DDE	5.E-06	ND
4,4'-DDT	4.E-06	0.3
Total Chlordane	6.E-07	0.04
Dieldrin	1.E-05	0.2
Methyl mercury	ND	0.5
Exposure Route Total	5.E-03	140
Exposure Point Total	5.E-03	140
Exposure Medium Total	5.E-03	140

ND - not determined because a toxicity value is unavailable for this exposure route.
mg/kg - milligram per kilogram

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Table 14: Summary of CTE Risk/Hazard for an Adult

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	3.E-04	ND
TCDD TEQ (PCBs)	9.E-05	ND
Total PCBs	4.E-05	16
4,4'-DDD	4.E-07	ND
4,4'-DDE	1.E-06	ND
4,4'-DDT	3.E-07	0.01
Total Chlordane	6.E-06	0.3
Dieldrin	4.E-06	0.04
Methyl mercury	ND	0.4
Exposure Route Total	4.E-04	16
Exposure Point Total	4.E-04	16
Exposure Medium Total	4.E-04	16
Crab Ingestion		
TCDD TEQ (D/F)	9.E-04	ND
TCDD TEQ (PCBs)	2.E-03	ND
Total PCBs	2.E-04	59
4,4'-DDD	1.E-06	ND
4,4'-DDE	3.E-06	ND
4,4'-DDT	2.E-06	0.1
Total Chlordane	4.E-07	0.02
Dieldrin	8.E-06	0.1
Methyl mercury	ND	0.2
Exposure Route Total	3.E-03	60
Exposure Point Total	3.E-03	60
Exposure Medium Total	3.E-03	60

ND - not determined because a toxicity value is not available for this exposure route.
mg/kg - milligram per kilogram

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Table 15: Summary of CTE Risk/Hazard for an Adolescent

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	2.E-04	ND
TCDD TEQ (PCBs)	5.E-05	ND
Total PCBs	2.E-05	13
4,4'-DDD	2.E-07	ND
4,4'-DDE	6.E-07	ND
4,4'-DDT	2.E-07	0.01
Total Chlordane	4.E-06	0.2
Dieldrin	3.E-06	0.04
Methyl mercury	ND	0.3
Exposure Route Total	2.E-04	14
Exposure Point Total	2.E-04	14
Exposure Medium Total	2.E-04	14
Crab Ingestion		
TCDD TEQ (D/F)	5.E-04	ND
TCDD TEQ (PCBs)	1.E-03	ND
Total PCBs	9.E-05	52
4,4'-DDD	6.E-07	ND
4,4'-DDE	2.E-06	ND
4,4'-DDT	1.E-06	0.1
Total Chlordane	2.E-07	0.01
Dieldrin	5.E-06	0.1
Methyl mercury	ND	0.2
Exposure Route Total	2.E-03	53
Exposure Point Total	2.E-03	53
Exposure Medium Total	2.E-03	53

ND - not determined because a toxicity value is not available for this exposure route.
mg/kg - milligram per kilogram

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Table 16: Summary of CTE Risk/Hazard for a Child

Chemical	Cancer Risk	Hazard Quotient
Fish Ingestion		
TCDD TEQ (D/F)	1.E-04	ND
TCDD TEQ (PCBs)	5.E-05	ND
Total PCBs	2.E-05	24
4,4'-DDD	2.E-07	ND
4,4'-DDE	5.E-07	ND
4,4'-DDT	1.E-07	0.02
Total Chlordane	3.E-06	0.4
Dieldrin	2.E-06	0.1
Methyl mercury	ND	0.6
Exposure Route Total	2.E-04	25
Exposure Point Total	2.E-04	25
Exposure Medium Total	2.E-04	25
Crab Ingestion		
TCDD TEQ (D/F)	4.E-04	ND
TCDD TEQ (PCBs)	9.E-04	ND
Total PCBs	7.E-05	87
4,4'-DDD	5.E-07	ND
4,4'-DDE	2.E-06	ND
4,4'-DDT	1.E-06	0.2
Total Chlordane	2.E-07	0.02
Dieldrin	4.E-06	0.1
Methyl mercury	ND	0.3
Exposure Route Total	1.E-03	87
Exposure Point Total	1.E-03	87
Exposure Medium Total	1.E-03	87

ND - not determined because a toxicity value is not available for this exposure route.
mg/kg - milligram per kilogram

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Appendix B

Supporting Tables for
Ecological Risk Assessment Summary

Table B-1: Ecological Receptors and Exposure Pathways of Concern

Exposure Media	Sensitive Environment (Y/N)	Receptor	Endangered/ Threatened Species (Y/N)	Potential Exposure Routes	Assessment Endpoints	Measurement Endpoints
Sediment	N	Benthic Organisms	N	Ingestion and dermal contact with chemicals in sediment, ingestion of contaminated prey, ingestion and dermal contact with contaminated surface water	Protection and maintenance (*i.e.*, survival, growth, and reproduction) of benthic invertebrate communities that serve as a forage base for fish and wildlife populations.	Comparison of site sediment concentrations to sediment benchmarks
Mud Flat Sediments		Macroinvertebrates: Blue Crab, Grass Shrimp				
Contaminated Prey	N	Demersal Fish: Mummichog	N	Ingestion of contaminated prey, dermal contact with surface water, and incidental ingestion of surface water.	Protection and maintenance (*i.e.*, survival, growth, and reproduction) of demersal, benthivorous fish populations that serve as a forage base for fish and wildlife populations.	Residue based assessment: Comparison of tissue concentrations to CBRs.
Contaminated Prey	N	Pelagic Fish: White Perch/American Eel	N	Ingestion of contaminated prey, dermal contact with surface water, and incidental ingestion of surface water.	Protection and maintenance (*i.e.*, survival, growth, and reproduction) of piscivorous, or semi-piscivorous fish populations that serve as a forage base for wildlife populations or sports fishery.	Residue based assessment: Comparison of tissue concentrations to CBRs.
Contaminated Prey	N	Aquatic Bird: Great Blue Herron	N	Ingestion of contaminated prey, dermal conact with surface water, and incidental ingestion of sediment.	Protection and maintenance (*i.e.*, survival, growth, and reproduction) of aquatic bird populations.	Dose Assessment: Species-specific modeled exposures compared to TRVs.
		Aquatic Bird:Herring Gull Embryo	N	Maternal transfer of chemicals from maternal ingestion of contaminated prey, dermal conact with surface water, and incidental ingestion of sediment.		Residue based assessment: Comparison of tissue concentrations to CBRs.
Contaminated Prey	N	Mink	N	Ingestion of contaminated prey, surface water, and incidental ingestion of sediment.	Protection and maintenance (*i.e.*, survival, growth, and reproduction) of piscivorous mammal populations.	Dose Assessment: Species-specific modeled exposures compared to TRVs.

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Table B-2: Exposure Point Concentration Summary for Sediment

Scenario Timeframe:	Current
Media:	Sediment
Exposure Media	Sediment

Chemical of Potential Ecological Concern		Units	Concentration					Frequency of Detect	Exposure Point Concentration (ppm)	Statistic [1]
			Minimum (ppm)	Minimum Qualifier	Maximum (ppm)	Maximum Qualifier	Arithmetic Mean			
Copper		µg/g	12		2470		217	234/234	236	95% Upper Confidence Limit
Dieldrin		µg/g	0.0014	DJ	0.141	PDJ	0.014	106/236	0.019	95% Upper Confidence Limit
Lead		µg/g	4.4		1550		328	225/225	375	95% Upper Confidence Limit
Mercury		µg/g	0.05	U	11	M	3.1	230/232	3.6	95% Upper Confidence Limit
LMW PAH		µg/g	0.007		1411		13.7	232 [2]	41	95% Upper Confidence Limit
HMW PAH		µg/g	1.8		1373		34.4	231 [2]	61	95% Upper Confidence Limit
Total PCBs (sum of Aroclors) [3]		µg/g	0.056		17.4		1.3	238 [2]	1.8	95% Upper Confidence Limit
Total DDT [4]		µg/g	0.0061		6.0		0.23	245 [2]	0.38	95% Upper Confidence Limit
TCDD TEQ (PCDD/F)	Mammal	µg/g	0.0000036		0.020		0.00078	232 [2]	0.0016	95% Upper Confidence Limit
	Bird	µg/g	0.0000016		0.025		0.00087	232 [2]	0.0018	95% Upper Confidence Limit
	Fish	µg/g	0.0000016		0.020		0.00078	232 [2]	0.0016	95% Upper Confidence Limit
TCDD TEQ (PCB)	Mammal	µg/g	0.00000081		0.00017		0.000036	230 [2]	0.000045	95% Upper Confidence Limit
	Bird	µg/g	0.00000027		0.0036		0.0054	230 [2]	0.00075	95% Upper Confidence Limit
	Fish	µg/g	0.00000014		0.000017		0.0000030	230 [2]	0.0000038	95% Upper Confidence Limit

[1] 95 percent UCLs calculated based on the data queries from PREmis and Contaminant Assessment and Reduction Project databases; samples included in the 95 percent UCL calculations are listed in Attachment 1 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b). 95 percent UCLs on the mean calculated using USEPA ProUCL software (Version 3.0); output files are included in Attachment 3 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).

[2] Frequency of detects could not be determined for calculated totals. Not all constituents that make up the aggregate were detected in all of the samples.

[3] Total PCBs represent the non-dioxin-like PCBs.

[4] The EPC for Total DDT is less than the sum of the EPCs for DDD, DDE, and DDT as a result of calculating 95 percent UCLs.

µg/g = microgram per gram (equivalent to ppm = parts per million)

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Table B-3: Exposure Point Concentration Summary for Crab Tissue

Scenario Timeframe:	Current
Media:	Sediment
Exposure Media	Crab Tissue [1]

Chemical of Potential Ecological Concern		Units	Concentration					Frequency of Detect	Exposure Point Concentration (ppm)	Statistic [2]
			Minimum (ppm)	Minimum Qualifier	Maximum (ppm)	Maximum Qualifier	Arithmetic Mean			
Copper		µg/g	8.4		78.5		30.4	64/64	35.3	95% Upper Confidence Limit
Dieldrin		µg/g	0.00075		0.10		0.11	14/77	0.022	95% Upper Confidence Limit
Lead		µg/g	0.055	U	2.4		0.46	61/71	0.55	95% Upper Confidence Limit
Mercury		µg/g	0.025	NJL	0.28		0.088	79/86	0.097	95% Upper Confidence Limit
LMW PAH		µg/g	0.0082		0.84		0.10	74 [3]	0.15	95% Upper Confidence Limit
HMW PAH		µg/g	0.012		0.76		0.11	73 [3]	0.16	95% Upper Confidence Limit
Total PCBs (sum of Aroclors) [4]		µg/g	0.082		14		2.7	79 [3]	5.5	95% Upper Confidence Limit
Total DDT [5]		µg/g	0.0034		2.6		0.26	80 [3]	0.56	95% Upper Confidence Limit
TCDD TEQ (PCDD/F)	Mammal	µg/g	0.0000023		0.00075		0.00012	75 [3]	0.00022	95% Upper Confidence Limit
	Bird	µg/g	0.0000036		0.00093		0.000150	75 [3]	0.00027	95% Upper Confidence Limit
	Fish	µg/g	0.0000023		0.00074		0.00012	75 [3]	0.00022	95% Upper Confidence Limit
TCDD TEQ (PCB)	Mammal	µg/g	0.00000046		0.0036		0.00011	76 [3]	0.00044	95% Upper Confidence Limit
	Bird	µg/g	0.0000020		0.025		0.00070	76 [3]	0.00280	95% Upper Confidence Limit
	Fish	µg/g	0.000000022		0.00021		0.0000064	76 [3]	0.000025	95% Upper Confidence Limit

[1] EPC derived from entire blue crab data (including hepatopancreas)

[2] 95 percent UCLs calculated based on the data queries from PREmis and Contaminant Assessment and Reduction Project databases; samples included in the 95 percent UCL calculations are listed in Attachment 1 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b). 95 percent UCLs on the mean calculated using USEPA ProUCL software (Version 3.0); output files are included in Attachment 3 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).

[3] Frequency of detects could not be determined for calculated totals. Not all constituents that make up the aggregate were detected in all of the samples.

[4] Total PCBs represent the non-dioxin-like PCBs.

[5] The EPC for total DDT is less than the sum of the EPCs for DDD, DDE, and DDT as a result of calculating 95 percent UCLs.

µg/g = microgram per gram (equivalent to ppm = parts per million)

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Table B-4: Exposure Point Concentration Summary for Mummichog Tissue

Scenario Timeframe:	Current
Media:	Sediment
Exposure Media	Mummichog Tissue

Chemical of Potential Ecological Concern		Units	Concentration					Frequency of Detect	Exposure Point Concentration (ppm)	Statistic [1]
			Minimum (ppm)	Minimum Qualifier	Maximum (ppm)	Maximum Qualifier	Arithmetic Mean			
Copper		µg/g	1.9	B	7.2	EJ	3.7	58/58	3.9	95% Upper Confidence Limit
Dieldrin		µg/g	0.0017	U	0.011	P	0.0031	10/61	0.0043	95% Upper Confidence Limit
Lead		µg/g	0.13	U	2.8		0.71	25/30	1.2	95% Upper Confidence Limit
Mercury		µg/g	0.019	J	0.15		0.039	63/67	0.042 [2]	95% Upper Confidence Limit
LMW PAH		µg/g	0.030		0.42		0.13	61 [3]	0.17	95% Upper Confidence Limit
HMW PAH		µg/g	0.0010		0.11		0.061	61 [3]	0.06	95% Upper Confidence Limit
Total PCBs (sum of Aroclors) [4]		µg/g	0.12		1.2		0.67	61 [3]	0.72	95% Upper Confidence Limit
Total DDT [5]		µg/g	0.00046		0.37		0.074	62 [3]	0.088	95% Upper Confidence Limit
TCDD TEQ (PCDD/F)	Mammal	µg/g	0.0000056		0.00084		0.000078	62 [3]	0.00015	95% Upper Confidence Limit
	Bird	µg/g	0.0000067		0.00084		0.000081	62 [3]	0.00015	95% Upper Confidence Limit
	Fish	µg/g	0.0000055		0.00084		0.000078	62 [3]	0.00014	95% Upper Confidence Limit
TCDD TEQ (PCB)	Mammal	µg/g	0.0000019		0.000043		0.000026	61 [3]	0.000027	95% Upper Confidence Limit
	Bird	µg/g	0.0000042		0.00057		0.00016	61 [3]	0.00020	95% Upper Confidence Limit
	Fish	µg/g	0.000000095		0.0000033		0.0000016	61 [3]	0.0000017	95% Upper Confidence Limit

[1] 95 percent UCLs calculated based on the data queries from PREmis and Contaminant Assessment and Reduction Project databases; samples included in the 95 percent UCL calculations are listed in Attachment 1 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b). 95 percent UCLs on the mean calculated using USEPA ProUCL software (Version 3.0); output files are included in Attachment 3 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).

[2] In the instance when ProUCL recommended more than one value, the first value (Student's-t UCL) was selected.

[3] Frequency of detects could not be determined for calculated totals. Not all constituents that make up the aggregate were detected in all of the samples.

[4] Total PCBs represent the non-dioxin-like PCBs.

[5] The EPC for total DDT is less than the sum of the EPCs for DDD, DDE, and DDT as a result of calculating 95 percent UCLs.

µg/g = microgram per gram (equivalent to ppm = parts per million)

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Table B-5: Exposure Point Concentration Summary for American Eel/White Perch

Scenario Timeframe:	Current
Media:	Sediment
Exposure Media	American Eel/White Perch Tissue [1]

Chemical of Potential Ecological Concern		Units	Concentration					Frequency of Detect	Exposure Point Concentration (ppm)	Statistic [2]
			Minimum (ppm)	Minimum Qualifier	Maximum (ppm)	Maximum Qualifier	Arithmetic Mean			
Copper		µg/g	0.31	B	36.7		8.8	38/38	24.8	95% Upper Confidence Limit
Dieldrin		µg/g	0.0003	U	0.140		0.022	38-77	0.027	95% Upper Confidence Limit
Lead		µg/g	0.055	U	1.6		0.40	17/29	0.63	95% Upper Confidence Limit
Mercury		µg/g	0.079		0.93		0.32	87/87	0.35	95% Upper Confidence Limit
LMW PAH		µg/g	0.023		0.80		0.15	64 [3]	0.17	95% Upper Confidence Limit
HMW PAH		µg/g	0.011		0.35		0.087	64 [3]	0.10	95% Upper Confidence Limit
Total PCBs (sum Aroclors) [4]		µg/g	0.083		14		2.9	77 [3]	3.4	95% Upper Confidence Limit
Total DDT [5]		µg/g	0.023		2.5		0.42	77 [3]	0.52	95% Upper Confidence Limit
TCDD TEQ (PCDD/F)	Mammal	µg/g	0.0000052		0.00048		0.00016	66 [3]	0.00025	95% Upper Confidence Limit
	Bird	µg/g	0.0000051		0.00052		0.00017	66 [3]	0.00028	95% Upper Confidence Limit
	Fish	µg/g	0.0000051		0.00048		0.00016	66 [3]	0.00025	95% Upper Confidence Limit
TCDD TEQ (PCB)	Mammal	µg/g	0.000013		0.00022		0.000065	77 [3]	0.000076	95% Upper Confidence Limit
	Bird	µg/g	0.000030		0.0015		0.00058	77 [3]	0.00086	95% Upper Confidence Limit
	Fish	µg/g	8.1E-07		0.000016		0.0000045	77 [3]	0.0000051	95% Upper Confidence Limit

[1] EPC derived from a combination of AE/WP tissue concentrations.

[2] 95 percent UCLs calculated based on the data queries from PREmis and Contaminant Assessment and Reduction Project databases; samples included in the 95 percent UCL calculations are listed in Attachment 1 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b). 95 percent UCLs on the mean calculated using USEPA ProUCL software (Version 3.0); output files are included in Attachment 3 of the Risk Assessment (Appendix C of the FFS; Malcolm Pirnie, Inc., 2007b).

[3] Frequency of detects could not be determined for calculated totals. Not all constituents that make up the aggregate were detected in all of the samples.

[4] Total PCBs represent the non-dioxin-like PCBs.

[5] The EPC for total DDT is less than the sum of the EPCs for DDD, DDE, and DDT as a result of calculating 95 percent UCLs.

µg/g = microgram per gram (equivalent to ppm = parts per million)

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Appendix C

Supporting Tables for
Estimates of Future Hazards for Ecological Receptors

Table C-1: Summary of Hazards for Benthic Macroinvertebrates – Sediment Benchmarks

COPEC	Monitored Natural Recovery		Primary Erosional Zone/ Primary Inventory Zone		Area of Focus	
	Year = 2018	Year = 2048	Year = 2018	Year = 2048	Year = 2018	Year = 2048
Copper	**4.1E+00**	**2.1E+00**	**3.9E+00**	**2.0E+00**	**2.4E+00**	**1.2E+00**
Lead	**5.0E+00**	**2.3E+00**	**4.8E+00**	**2.2E+00**	**3.2E+00**	**1.5E+00**
Mercury	**1.0E+01**	**3.3E+00**	**9.1E+00**	**2.9E+00**	**4.1E+00**	**1.3E+00**
Mercury (methyl)	**1.0E+01**	**3.3E+00**	**9.1E+00**	**2.9E+00**	**4.1E+00**	**1.3E+00**
LMW PAH	**6.0E+01**	**6.0E+01**	**6.0E+01**	**6.0E+01**	**2.8E+01**	**2.8E+01**
HMW PAH	**5.0E+01**	**5.0E+01**	**5.0E+01**	**5.0E+01**	**3.6E+01**	**3.6E+01**
Aroclor, Total	**2.5E+01**	**5.7E+00**	**2.2E+01**	**5.1E+00**	**1.7E+01**	**3.9E+00**
Dieldrin	**1.0E+03**	**1.0E+03**	**9.4E+02**	**9.4E+02**	**2.3E+02**	**2.3E+02**
Total DDT	**1.2E+02**	**4.4E+01**	**1.1E+02**	**3.8E+01**	**4.4E+01**	**1.5E+01**
TCDD TEQ (PCDD/F)	**2.8E+02**	**7.5E+01**	**1.9E+02**	**5.6E+01**	**1.3E+01**	**4.0E+00**
TCDD TEQ (PCBs)	2.5E-01	8.2E-02	2.3E-01	4.1E-02	1.6E-01	4.1E-02
Total TCDD TEQ	**2.8E+02**	**7.5E+01**	**1.9E+02**	**5.6E+01**	**1.3E+01**	**4.1E+00**
Total	**1.6E+03**	**1.3E+03**	**1.4E+03**	**1.2E+03**	**3.8E+02**	**3.3E+02**

Bolded values indicate hazards greater than 1.0

Table C-2: Summary of Hazards for Blue Crab – Critical Body Residues

COPEC	Monitored Natural Recovery				Primary Erosional Zone/ Primary Inventory Zone				Area of Focus			
	Year = 2018		Year = 2048		Year = 2018		Year = 2048		Year = 2018		Year = 2048	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	**2.3E+02**	**2.3E+01**	**1.1E+02**	**1.1E+01**	**2.2E+02**	**2.2E+01**	**1.1E+02**	**1.1E+01**	**1.3E+02**	**1.3E+01**	**6.7E+01**	**6.7E+00**
Lead	6.4E-01	6.4E-02	3.0E-01	3.0E-02	6.1E-01	6.1E-02	2.8E-01	2.8E-02	4.0E-01	4.0E-02	1.9E-01	1.9E-02
Mercury	**4.6E+00**	4.6E-01	**1.5E+00**	1.5E-01	**4.0E+00**	4.0E-01	**1.3E+00**	1.3E-01	**1.8E+00**	1.8E-01	5.8E-01	5.8E-02
Mercury (methyl)	**4.6E+00**	4.6E-01	**1.5E+00**	1.5E-01	**4.0E+00**	4.0E-01	**1.3E+00**	1.3E-01	**1.8E+00**	1.8E-01	5.8E-01	5.8E-02
LMW PAH	**1.1E+01**	**1.1E+00**	**1.1E+01**	**1.1E+00**	**1.1E+01**	**1.1E+00**	**1.1E+01**	**1.1E+00**	**5.3E+00**	5.3E-01	**5.3E+00**	5.3E-01
HMW PAH	**1.2E+01**	**1.2E+00**	**1.2E+01**	**1.2E+00**	**1.2E+01**	**1.2E+00**	**1.2E+01**	**1.2E+00**	**8.8E+00**	8.8E-01	**8.8E+00**	8.8E-01
Aroclor, Total	**2.8E+00**	**1.1E+00**	6.3E-01	2.4E-01	**2.5E+00**	9.4E-01	5.6E-01	2.1E-01	**1.9E+00**	7.2E-01	4.3E-01	1.6E-01
Dieldrin	**1.4E+00**	1.7E-01	**1.4E+00**	1.7E-01	**1.3E+00**	1.6E-01	**1.3E+00**	1.6E-01	3.2E-01	4.0E-02	3.2E-01	4.0E-02
Total DDT	**1.2E+03**	**1.2E+02**	**4.2E+02**	**4.2E+01**	**1.0E+03**	**1.0E+02**	**3.6E+02**	**3.6E+01**	**4.2E+02**	**4.2E+01**	**1.5E+02**	**1.5E+01**
TCDD TEQ (PCDD/F)	**9.1E+02**	**1.0E+02**	**2.4E+02**	**2.8E+01**	**6.0E+02**	**7.0E+01**	**1.8E+02**	**2.1E+01**	**4.2E+01**	**4.8E+00**	**1.3E+01**	**1.5E+00**
TCDD TEQ (PCBs)	**1.1E+01**	**1.2E+00**	**3.6E+00**	4.2E-01	**1.0E+01**	**1.2E+00**	**1.8E+00**	2.1E-01	**7.2E+00**	8.3E-01	**1.8E+00**	2.1E-01
Total TCDD TEQ	**9.2E+02**	**1.1E+02**	**2.5E+02**	**2.8E+01**	**6.1E+02**	**7.1E+01**	**1.8E+02**	**2.1E+01**	**4.9E+01**	**5.6E+00**	**1.5E+01**	**1.7E+00**
Total	**2.4E+03**	**2.5E+02**	**8.1E+02**	**8.4E+01**	**1.9E+03**	**2.0E+02**	**6.8E+02**	**7.1E+01**	**6.2E+02**	**6.4E+01**	**2.5E+02**	**2.5E+01**

Bolded values indicate hazards greater than 1.0

Subject to Attorney Client, Work Product, Deliverable Process and/or Joint Prosecution Privileges; FOIA/OPRA Exempt

Table C-3: Summary of Hazards for White Perch/American Eel – Critical Body Residues

COPEC	Monitored Natural Recovery				Primary Erosional Zone/ Primary Inventory Zone				Area of Focus			
	Year = 2018		Year = 2048		Year = 2018		Year = 2048		Year = 2018		Year = 2048	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	**2.8E+03**	**2.8E+02**	**1.4E+03**	**1.4E+02**	**2.7E+03**	**2.7E+02**	**1.4E+03**	**1.4E+02**	**1.7E+03**	**1.7E+02**	**8.4E+02**	**8.4E+01**
Lead	**1.0E+01**	**1.0E+00**	**4.7E+00**	4.7E-01	**9.8E+00**	9.8E-01	**4.5E+00**	4.5E-01	**6.4E+00**	6.4E-01	**3.0E+00**	3.0E-01
Mercury	**2.6E+01**	**2.6E+00**	**8.4E+00**	8.4E-01	**2.3E+01**	**2.3E+00**	**7.4E+00**	7.4E-01	**1.0E+01**	**1.0E+00**	**3.4E+00**	3.4E-01
Mercury (methyl)	**2.6E+01**	**2.6E+00**	**8.4E+00**	8.4E-01	**2.3E+01**	**2.3E+00**	**7.4E+00**	7.4E-01	**1.0E+01**	**1.0E+00**	**3.4E+00**	3.4E-01
LMW PAH	**1.8E+00**	1.8E-01	**1.8E+00**	1.8E-01	**1.7E+00**	1.7E-01	**1.7E+00**	1.7E-01	8.2E-01	8.2E-02	8.2E-01	8.2E-02
HMW PAH	**1.0E+00**	1.0E-01	**1.0E+00**	1.0E-01	**1.0E+00**	1.0E-01	**1.0E+00**	1.0E-01	7.4E-01	7.4E-02	7.4E-01	7.4E-02
Aroclor, Total	**4.9E+02**	**4.9E+01**	**1.1E+02**	**1.1E+01**	**4.4E+02**	**4.4E+01**	**9.9E+01**	**9.9E+00**	**3.4E+02**	**3.4E+01**	**7.6E+01**	**7.6E+00**
Dieldrin	**2.9E+00**	2.9E-01	**2.9E+00**	2.9E-01	**2.7E+00**	2.7E-01	**2.7E+00**	2.7E-01	6.8E-01	6.8E-02	6.8E-01	6.8E-02
Total DDT	**9.2E+03**	**2.0E+02**	**3.2E+03**	**7.0E+01**	**7.9E+03**	**1.7E+02**	**2.8E+03**	**6.0E+01**	**3.3E+03**	**7.1E+01**	**1.1E+03**	**2.5E+01**
TCDD TEQ (PCDD/F)	**5.3E+00**	**3.1E+00**	**1.4E+00**	8.2E-01	**3.5E+00**	**2.1E+00**	**1.1E+00**	6.2E-01	2.4E-01	1.4E-01	7.5E-02	4.4E-02
TCDD TEQ (PCBs)	3.4E-02	2.0E-02	1.1E-02	6.6E-03	3.2E-02	1.9E-02	5.6E-03	3.3E-03	2.2E-02	1.3E-02	5.6E-03	3.3E-03
Total TCDD TEQ	**5.3E+00**	**3.1E+00**	**1.4E+00**	8.3E-01	**3.5E+00**	**2.1E+00**	**1.1E+00**	6.2E-01	2.6E-01	1.5E-01	8.1E-02	4.7E-02
Total	**1.3E+04**	**5.5E+02**	**4.8E+03**	**2.3E+02**	**1.1E+04**	**5.0E+02**	**4.3E+03**	**2.1E+02**	**5.3E+03**	**2.8E+02**	**2.1E+03**	**1.2E+02**

Bolded values indicate hazards greater than 1.0

Table C-4: Summary of Hazards for Mummichog – Critical Body Residues

COPEC	Monitored Natural Recovery				Primary Erosional Zone/ Primary Inventory Zone				Area of Focus			
	Year = 2018		Year = 2048		Year = 2018		Year = 2048		Year = 2018		Year = 2048	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	**1.2E+03**	**1.2E+02**	**5.9E+02**	**5.9E+01**	**1.1E+03**	**1.1E+02**	**5.6E+02**	**5.6E+01**	**6.9E+02**	**6.9E+01**	**3.5E+02**	**3.5E+01**
Lead	**1.8E+01**	**1.8E+00**	**8.5E+00**	8.5E-01	**1.8E+01**	**1.8E+00**	**8.1E+00**	8.1E-01	**1.1E+01**	**1.1E+00**	**5.3E+00**	5.3E-01
Mercury	**3.2E+00**	3.2E-01	**1.0E+00**	1.0E-01	**2.8E+00**	2.8E-01	9.0E-01	9.0E-02	**1.3E+00**	1.3E-01	4.1E-01	4.1E-02
Mercury (methyl)	**3.2E+00**	3.2E-01	**1.0E+00**	1.0E-01	**2.8E+00**	2.8E-01	9.0E-01	9.0E-02	**1.3E+00**	1.3E-01	4.1E-01	4.1E-02
LMW PAH	**1.5E+00**	1.5E-01	**1.5E+00**	1.5E-01	**1.5E+00**	1.5E-01	**1.5E+00**	1.5E-01	6.9E-01	6.9E-02	6.9E-01	6.9E-02
HMW PAH	7.3E-01	7.3E-02	7.3E-01	7.3E-02	7.3E-01	7.3E-02	7.3E-01	7.3E-02	5.2E-01	5.2E-02	5.2E-01	5.2E-02
Aroclor, Total	**1.2E+02**	**1.2E+01**	**2.6E+01**	**2.6E+00**	**1.0E+02**	**1.0E+01**	**2.3E+01**	**2.3E+00**	**7.9E+01**	**7.9E+00**	**1.8E+01**	**1.8E+00**
Dieldrin	4.1E-01	4.1E-02	4.1E-01	4.1E-02	3.8E-01	3.8E-02	3.8E-01	3.8E-02	9.5E-02	9.5E-03	9.5E-02	9.5E-03
Total DDT	**1.6E+03**	**3.5E+01**	**5.7E+02**	**1.2E+01**	**1.4E+03**	**3.0E+01**	**4.9E+02**	**1.1E+01**	**5.7E+02**	**1.2E+01**	**2.0E+02**	**4.3E+00**
TCDD TEQ (PCDD/F)	**2.6E+00**	**1.6E+00**	7.1E-01	4.1E-01	**1.8E+00**	**1.0E+00**	5.3E-01	3.1E-01	1.2E-01	7.1E-02	3.8E-02	2.2E-02
TCDD TEQ (PCBs)	1.2E-02	6.9E-03	3.9E-03	2.3E-03	1.1E-02	6.6E-03	2.0E-03	1.2E-03	7.9E-03	4.6E-03	2.0E-03	1.2E-03
Total TCDD TEQ	**2.7E+00**	**1.6E+00**	7.1E-01	4.2E-01	**1.8E+00**	**1.0E+00**	5.3E-01	3.1E-01	1.3E-01	7.6E-02	4.0E-02	2.3E-02
Total	**2.9E+03**	**1.7E+02**	**1.2E+03**	**7.6E+01**	**2.7E+03**	**1.6E+02**	**1.1E+03**	**7.1E+01**	**1.4E+03**	**9.1E+01**	**5.7E+02**	**4.2E+01**

Bolded values indicate hazards greater than 1.0

Subject to Attorney Client, Work Product, Deliverable Process and/or Joint Prosecution Privileges; FOIA/OPRA Exempt

Table C-5: Summary of Hazards for Great Blue Heron – Ingestion of Fish and Sediment

COPEC	Monitored Natural Recovery				Primary Erosional Zone/ Primary Inventory Zone				Area of Focus			
	Year = 2018		Year = 2048		Year = 2018		Year = 2048		Year = 2018		Year = 2048	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	3.7E-01	1.2E-01	1.9E-01	6.3E-02	3.6E-01	1.2E-01	1.8E-01	6.0E-02	2.2E-01	7.3E-02	1.1E-01	3.7E-02
Lead	7.6E-01	3.8E-01	3.5E-01	1.8E-01	7.3E-01	3.6E-01	3.4E-01	1.7E-01	4.8E-01	2.4E-01	2.2E-01	1.1E-01
Mercury	**2.9E+00**	2.9E-01	9.2E-01	9.2E-02	**2.5E+00**	2.5E-01	8.1E-01	8.1E-02	**1.1E+00**	1.1E-01	3.7E-01	3.7E-02
LMW PAH	-	-	-	-	-	-	-	-	-	-	-	-
HMW PAH	-	-	-	-	-	-	-	-	-	-	-	-
Aroclor, Total	**1.3E+00**	3.2E-01	2.9E-01	7.3E-02	**1.1E+00**	2.9E-01	2.6E-01	6.5E-02	8.7E-01	2.2E-01	2.0E-01	4.9E-02
Dieldrin	4.4E-02	8.3E-04	4.4E-02	8.3E-04	4.1E-02	7.7E-04	4.1E-02	7.7E-04	1.0E-02	1.9E-04	1.0E-02	1.9E-04
Total DDx	**1.3E+01**	**1.3E+00**	**4.5E+00**	4.5E-01	**1.1E+01**	**1.1E+00**	**3.9E+00**	3.9E-01	**4.5E+00**	4.5E-01	**1.6E+00**	1.6E-01
TCDD TEQ (PCDD/F)	**1.7E+01**	**1.7E+00**	**5.4E+00**	5.4E-01	**1.2E+01**	**1.2E+00**	**3.3E+00**	3.3E-01	7.5E-01	7.5E-02	2.5E-01	2.5E-02
TCDD TEQ (PCBs)	**1.4E+01**	**1.4E+00**	**3.6E+00**	3.6E-01	**1.3E+01**	**1.3E+00**	**3.1E+00**	3.1E-01	**9.6E+00**	9.6E-01	**2.4E+00**	2.4E-01
Total TCDD TEQ	**3.1E+01**	**3.1E+00**	**9.0E+00**	9.0E-01	**2.4E+01**	**2.4E+00**	**6.4E+00**	6.4E-01	**1.0E+01**	**1.0E+00**	**2.6E+00**	2.6E-01
Total	**5.0E+01**	**5.5E+00**	**1.5E+01**	**1.8E+00**	**4.0E+01**	**4.6E+00**	**1.2E+01**	**1.4E+00**	**1.8E+01**	**2.1E+00**	**5.1E+00**	**6.6E-01**

Bolded values indicate hazards greater than 1.0

Table C-6: Summary of Hazards for Mink – Ingestion of Fish and Sediment

COPEC	Monitored Natural Recovery				Primary Erosional Zone/ Primary Inventory Zone				Area of Focus			
	Year = 2018		Year = 2048		Year = 2018		Year = 2048		Year = 2018		Year = 2048	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	6.0E-01	3.6E-01	3.0E-01	1.8E-01	5.8E-01	3.5E-01	2.9E-01	1.7E-01	3.5E-01	2.1E-01	1.8E-01	1.1E-01
Lead	3.2E-01	1.7E-01	1.5E-01	7.8E-02	3.1E-01	1.6E-01	1.4E-01	7.5E-02	2.0E-01	1.1E-01	9.3E-02	4.9E-02
Mercury	9.0E-01	2.8E-01	2.9E-01	8.9E-02	8.0E-01	2.4E-01	2.6E-01	7.8E-02	3.6E-01	1.1E-01	1.2E-01	3.5E-02
LMW PAH	-	-	-	-	-	-	-	-	-	-	-	-
HMW PAH	5.8E-01	5.8E-02	5.8E-01	5.8E-02	5.8E-01	5.8E-02	5.8E-01	5.8E-02	4.2E-01	4.2E-02	4.2E-01	4.2E-02
Aroclor, Total	**4.6E+00**	**3.8E+00**	**1.0E+00**	8.7E-01	**4.1E+00**	**3.4E+00**	9.3E-01	7.8E-01	**3.1E+00**	**2.6E+00**	7.1E-01	5.9E-01
Dieldrin	5.8E-01	2.9E-01	5.8E-01	2.9E-01	5.4E-01	2.7E-01	5.4E-01	2.7E-01	1.3E-01	6.7E-02	1.3E-01	6.7E-02
Total DDt	1.3E-01	2.5E-02	4.4E-02	8.8E-03	1.1E-01	2.2E-02	3.8E-02	7.6E-03	4.5E-02	8.9E-03	1.6E-02	3.1E-03
TCDD TEQ (PCDD/F)	**7.4E+02**	**2.7E+01**	**2.3E+02**	**8.3E+00**	**5.1E+02**	**1.8E+01**	**1.4E+02**	**5.0E+00**	**3.2E+01**	**1.1E+00**	**1.1E+01**	3.8E-01
TCDD TEQ (PCBs)	**6.4E+01**	**2.3E+00**	**1.8E+01**	6.5E-01	**6.4E+01**	**2.3E+00**	**1.8E+01**	6.5E-01	**4.5E+01**	**1.6E+00**	**9.1E+00**	3.2E-01
Total TCDD TEQ	**8.1E+02**	**2.9E+01**	**2.5E+02**	**8.9E+00**	**5.7E+02**	**2.1E+01**	**1.6E+02**	**5.6E+00**	**7.7E+01**	**2.8E+00**	**2.0E+01**	7.0E-01
Total	**8.1E+02**	**3.4E+01**	**2.5E+02**	**1.1E+01**	**5.8E+02**	**2.5E+01**	**1.6E+02**	**7.1E+00**	**8.2E+01**	**5.9E+00**	**2.1E+01**	**1.6E+00**

Bolded values indicate hazards greater than 1.0

Subject to Attorney Client, Work Product, Deliverable Process and/or Joint Prosecution Privileges; FOIA/OPRA Exempt